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by Martin E. Dale

EFFECT OF REMOVING UNDERSTORY ON GROWTH OF UPLAND OAK

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EFFECT OF REMOVING UNDERSTORY ON GROWTH OF UPLAND OAK

ABSTRACT

The amount of additional growth attributed to complete eradication of all woody understory vegetation varied for several widely scattered upland oak stands in the region. Based on paired-plot comparisons of 10 or more years' results, basal-area and cubic-volume growth usually increased slightly when the understory was eradicated. The amount of increase was related to (1) geographical stand location, (2) stand age, and (3) residual stocking of overstory trees. The greatest response to understory removal—an additional 0.75 square feet of basal area or about 12 cubic feet per acre per year—was found in very young stands located in the western part of the oak range where residual density of stocking after thinning was about 50 percent. However, results of this study indicate that for most upland oak stands in the region, understory-removal treatments would not greatly increase stand growth.

SMALL UNDERSTORY TREES and shrubs generally are not removed during a thinning operation in the upland oak type. Understory vegetation responds rapidly to the increased availability of sunlight, soil moisture, and nutrients; thus a vigorous and dense understory soon develops, particularly after heavy thinnings.

Little is known about the ability of this understory in hardwood stands to compete with the overstory trees for moisture or other growth factors, or how much a dense understory affects the growth of overstory trees. Some foresters working with hardwood stands are concerned that competition from a dense understory may retard growth of overstory trees.

In the early 1960s, we began several studies of understory control at widely separated locations in the upland oak region. Each study was designed to find out how much overstory growth was affected by completely eradicating understory in one particular set of stand conditions. All plots in each stand were about the same in stand age, site quality, and species composition; but these factors were different in different stands (table 1).

In this report, the long-term growth response for five understory control studies in the upland oak region are summarized and compared. If published separately, the results from these individual studies may seem contradictory because the growth response associated with understory removal differed with

(1) geographical location, (2) stand age, and (3) residual stocking level. However, based on the aggregate response of all studies in the upland oak region, a definite growth pattern begins to emerge, which leads to more apparent generalizations about the effect of understory treatments in most of the upland oak type.

METHODS

Study Design

All study plots were located in young even-aged upland oak stands of about average site quality. They were all well stocked before the initial thinning except the Iowa plots, which differed in stocking because of a thinning in 1950. The basic idea was to determine for each stand the effect on growth of complete understory removal by comparing the response of paired plots. In Kentucky and Ohio, each plot in the pair was adjacent, and the plots differed very little in age, site, number of trees, and basal area after thinning. In Iowa and Missouri, the plots in a pair were not necessarily adjacent; but we tried to pair the plots to keep stand conditions as uniform as possible in each pair. Then the understory-removal treatment was randomly assigned to one plot, and the other plot served as the control.

We anticipated that residual stocking would affect the density and rate of understory development. Percent stocking was calculated from Gingrich's (*1967*) equation (tree area in milacres$= -0.0507N + 0.1698 \Sigma D + 0.0317 \Sigma D^2$) and was expressed on a percentage basis by letting 1,000 milacres equal 100 percent stocking.

In Missouri, we assigned to each of the paired plots one of three different density levels between 30 and 70 percent stocking to see if the effect of understory removal was the same for all densities. All pairs in Kentucky were thinned to about 35 percent stocking, but in Ohio all plots were reduced to about 65 percent stocking. In Iowa, each of the five pairs was assigned a different density, from 50 to 95 percent stocking.

Table 1.—Average stand characteristics per acre after initial thinning for treated and untreated understories by location

Stand location	Understory treatment	Plots	Plot size	Principal species	Average age	Site index	Basal area	Trees	Stocking	Total volume
		No.	*Acres*		*Years*	*Feet*	*Sq. ft.*	*No.*	*Percent*	*Cu. ft.*
Eastern Kentucky	Treated	4	0.25	White oak	34	70	30	284	36	778
	Not treated	4	.25		34	70	31	283	38	827
Southeast[a] Ohio	Treated	3	.25	Mixed oak	51	73	69	177	64	2,212
	Not treated	3	.25		52	72	69	176	64	2,211
Southeast Missouri (1)	Treated	6	.50	Black oak	20	72	36	568	49	891
	Not treated	6	.50		22	70	41	418	50	942
Southeast Missouri (2)	Treated	6	.50	Black oak	40	68	50	167	48	1,386
	Not treated	6	.50		42	66	50	145	47	1,404
Southeast[b] Iowa	Treated	5	.20	White oak	37	59	67	332	70	1,568
	Not treated	5	.20		37	59	69	316	71	1,636

[a] Study established in cooperation with and on land owned by Mead Corporation.

[b] Established on Shimek State Forest in cooperation with Iowa Conservation Commission. All plots had received an earlier thinning in 1950.

Thinning Treatment

Every plot was thinned to the predetermined stocking level before understory treatment. We followed the same thinning procedure that was used in our stand-density studies. The objective was to leave a suitable number of the best stems as evenly spaced as possible on the plot. In general, we cut the larger cull and defective trees first, then competing trees of poor form and quality, then intermediate and suppressed trees of lower quality and value, and finally, if necessary, the lower value species of the main crown class. High-quality trees of desirable species were also cut when necessary to achieve a uniform spatial distribution. All trees smaller than 1.6 inches dbh were considered part of the understory. These were ignored during the thinning operation.

Plots in which the understory was removed differed very little from the control plots in average age, site index, residual basal area, or number of trees (table 1). Most of the stands were predominantly black or white oak, except in Ohio where the numbers of black, white, and chestnut oak were about equal. Tree size class differed among the stands from sapling to large poles; however, all stands were young, ranging between 20 and 50 years of age.

Understory Treatment

On plots selected for eradication of understory, all woody vegetation less than 1.6 inches dbh was killed in early spring after the thinning operation. The larger understory stems were generally cut by ax, and the stumps were sprayed with herbicide to prevent sprouting. Foliage spray was used to kill the smaller understory trees. Two or three followup treatments in subsequent years were usually required to eliminate all woody vegetation and prevent new growth from developing.

Understory stems were left alone after the overstory was thinned on all the control plots except in the Kentucky stand. In Kentucky, all the understory trees taller than 4.5 feet were cut on the control plots as well; but stumps were not sprayed with herbicides. Stump sprouts, new reproduction, and growth on the remaining understory stems created a dense and vigorous understory on the control plots within 2 years after treatment.

RESULTS

After 10 or more growing seasons, it is evident that some stands respond with an increase in growth when the understory is removed, and other stands show only a slight increase or none at all. Increased growth after understory removal seems to vary with (1) geographical location of the stand, (2) stand age, and (3) residual stocking.

Stand Growth

If the understory-removal treatment had no effect, one would expect the mean growth difference between treated and untreated plots to be about zero. Yet some of the differences were highly significant (table 2). Gross growth is more sensitive for detecting differences between treatments than net growth because the variance is much smaller for gross growth (table 3).

Two stands accounted for most of the differences in growth between treated and untreated plots: the 20-year-old black oak stand in Missouri and the 37-year-old white oak stand in Iowa. None of the other stands produced any significant difference in growth between treated and untreated plots. However, because we had only a few pairs of plots for comparison in each stand, the "t" test we used was not sensitive enough to detect such small differences in growth.

Undoubtedly small differences in growth response do exist; but additional plots would be needed to show whether or not this difference was statistically significant. The values in tables 2 and 3 could be used to compute the number of observations required to detect statistically significant differences. But, for practical purposes, a numerically small growth difference, even if we can show that it is statistically significant, is not important anyway.

Table 2.—Periodic annual growth per acre for treated and untreated understories for five stands

Stand location	Understory treatment	Growth period	Basal area		Stocking percent		Total cubic volume[a]		Merchantable cubic volume[b]	
			Net	Gross	Net	Gross	Net	Gross	Net	Gross
		Years	*Sq. ft.*	*Sq. ft.*	*Percent*	*Percent*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
Eastern Kentucky	Treated	10	2.50	2.60	2.13	2.26	77.8	80.6	57.0	59.0
	Not treated	10	2.38	2.50	1.99	2.15	75.8	78.9	55.5	57.7
	Difference		0.12	0.10	0.14	0.11	2.0	1.7	1.5	1.3
Southeast Ohio	Treated	10	1.41	2.18	0.89	1.63	77.6	102.6	56.6	75.0
	Not treated	10	1.46	2.19	.93	1.63	79.2	102.9	57.9	75.3
	Difference		−0.05	−0.01	−0.04	0.00	− 1.6	− 0.3	− 1.3	− 0.3
Southeast Missouri (1)	Treated	11	3.54	3.82	3.01	3.44	90.9	99.1	69.9	72.5
	Not treated	11	2.76	3.02	2.22	2.59	78.4	85.5	57.3	62.5
	Difference		0.78**	0.80**	0.79*	0.85**	12.5*	13.6*	12.6	10.0*
Southeast Missouri (2)	Treated	10	1.97	2.16	1.43	1.63	81.7	86.8	59.7	63.4
	Not treated	10	1.94	2.05	1.45	1.55	78.9	81.8	57.7	59.8
	Difference		0.03	0.11	−0.02	0.08	2.8	5.0	2.0	3.6
Southeast Iowa	Treated	12	2.67	2.97	2.01	2.34	92.1	99.8	66.1	71.7
	Not treated	12	2.14	2.39	1.59	1.88	76.7	82.6	56.1	60.3
	Difference		0.53	0.58**	0.42	0.46*	15.4	17.2	10.0	11.4

* Significant at the 5-percent level or greater.

**Significant at the 1-percent level or greater.

[a] All trees 2.6 inches dbh or larger, including bark, stump, and tip, but no branchwood.

[b] All trees 4.6 inches dbh or larger, excluding stump, bark, branches, and tip above 4.5-inch top dob.

Table 3.—Standard deviation of the mean for annual growth differences between treated and untreated plots

Stand location	Basal area		Stocking percent		Total cubic volume		Merchantable cubic volume	
	Net	Gross	Net	Gross	Net	Gross	Net	Gross
	Sq. ft.	*Sq. ft.*	*Pct.*	*Pct.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
Eastern Kentucky	0.17	0.08	0.16	0.05	5.60	3.03	4.06	2.21
Southeast Ohio	.35	.14	.29	.12	9.34	2.96	6.86	2.15
Southeast Missouri (1)	.16	.10	.21	.14	4.86	4.01	6.45	2.92
Southeast Missouri (2)	.16	.12	.15	.09	7.90	5.95	5.76	4.36
Southeast Iowa	.24	.12	.24	.11	9.24	6.99	6.16	4.44

Table 4.—Periodic net and gross annual basal-area growth per acre in Missouri by age, residual stocking, and understory treatment

Age class (years)	Understory treatment		Net growth, by stocking percent			Gross growth, by stocking percent		
			30	50	70	30	50	70
20	Treated	sq. ft.	3.58	3.80	3.26	3.68	3.91	3.85
	Not treated	sq. ft.	2.94	2.72	2.62	2.95	2.97	3.14
	Increase	percent	22	40	24	25	32	22
40	Treated	sq. ft.	1.96	2.28	1.66	2.08	2.31	2.08
	Not treated	sq. ft.	1.88	1.95	1.98	2.11	1.99	2.04
	Increase	percent	4	17	— 16	— 1	16	2

There are too few plots to determine whether the effect of understory removal differed with stand age or with residual stocking at each stand location. However, one-half of all our plots were located in black oak stands in Missouri; and these plots, representing two age classes and three stand-density levels, provide some clues about the effect of age and stocking level. Average growth for two treated and two untreated plots at each combination of age and stocking does indicate differences in response.

The absolute increase and the percentage increase in periodic annual growth due to understory treatment was greatest in the 20-year-old stand. This was true in terms of basal-area growth (table 4) and total cubic-foot volume growth (table 5). Gross basal-area growth in the younger stand increased on the treated plots by about 22 to 32 percent or about 0.7 to 1.0 square foot per acre per year, depending on stocking. The basal-area response was much less in the older stand, varying from a 1-percent decrease to a 16-percent increase. Gross volume growth was increased by as much as 21 cubic feet or 25 percent per year in the younger stand compared to 14 cubic feet or 18 percent in the older stand.

Gross growth, which includes mortality, is probably a better indicator of the treatment effect than net growth because net growth may fluctuate more because of an erratic mortality pattern. We had less mortality than expected on the untreated plots in the older stand with 70 percent stocking; but in gen-

Table 5.—Periodic net and gross total cubic-foot volume growth per acre in Missouri by age, residual stocking, and understory treatment

Age class (years)	Understory treatment	Net growth, by stocking percent 30	50	70	Gross growth, by stocking percent 30	50	70
20	Treated . . . . cu. ft. . .	93	102	78	96	105	96
	Not treated . . cu. ft.	82	77	76	82	84	90
	Increase . . percent	14	32	3	16	25	7
40	Treated . . . . cu. ft. . .	73	94	79	76	94	90
	Not treated . . cu. ft.	65	79	93	71	80	95
	Increase . . percent	12	19	−15	8	18	− 5

eral, the same trends were established, using either the net or gross values.

The difference in growth response between treated and untreated plots was closely related to the residual stocking after thinning. The largest growth difference was observed in both age classes when stands were thinned to a residual stocking of about 50 percent (tables 4 and 5). Although residual stocking for these plots was 50 percent initially, it averaged 65 percent over the entire growth period for the 20-year-old stand and about 58 percent for the 40-year-old stand. Thus the stocking percentage that gave the greatest growth difference was near the minimum density required for full site utilization — that is, about 58 percent of full stocking or curve B in the stocking guides for upland central hardwoods *(Roach and Gingrich 1968)*. The effect of removing the dense understory competition from plots reduced to 30 percent residual stocking was not as great, and this may be because each overstory tree already had all the growing space it presumably could use.

Individual Tree Growth

For most of the Iowa and Missouri plots, understory removal led to increased diameter growth of individual trees, but there was only a slight increase in Kentucky and none in Ohio. In Missouri, the increase varied with stand age and stocking much the same as stand growth varied. Average diameter growth of all surviving black oak trees was computed for each diameter class for both stands in Missouri. Average diameter growth per tree for treated and untreated plots is given for the 20-year-old stand in table 6 for each stocking level. Table 7 gives comparable diameter growth rates of black oak for the 40-year-old stand.

When growth rates from tables 6 and 7 are plotted, it is apparent that the diameter growth rate for a given size tree usually decreases as stand age or stocking percentage increases. In most cases, when the understory was eliminated, the growth per tree was greater for a given age, stocking, and tree size; the only exception in Missouri was the 40-year-old stand with 30-percent stocking. At 50-percent stocking, the mean diameter growth rate of all surviving black oak trees was 0.18 inch per year for the 20-year-old stand on the treated plots or about 0.03 inch (20 percent) more than on the plots with understory in place. In the older stand, at 50-percent stocking, the average diameter growth was 0.17 inch per year on the untreated plots, almost 0.03 inch more than on treated understory plots.

The effect of understory removal on annual diameter growth rate of white oak is illustrated in figure 1 for both the Kentucky and Iowa stands. Average diameter growth of white oak on the treated plots in Kentucky was about 0.16 inch per year compared to 0.15 inch on untreated plots — a gain of about 7 percent due to understory removal. Diameter growth of white oak in Iowa was much less, averaging about 0.11 inch per year on understory treated plots and 0.09

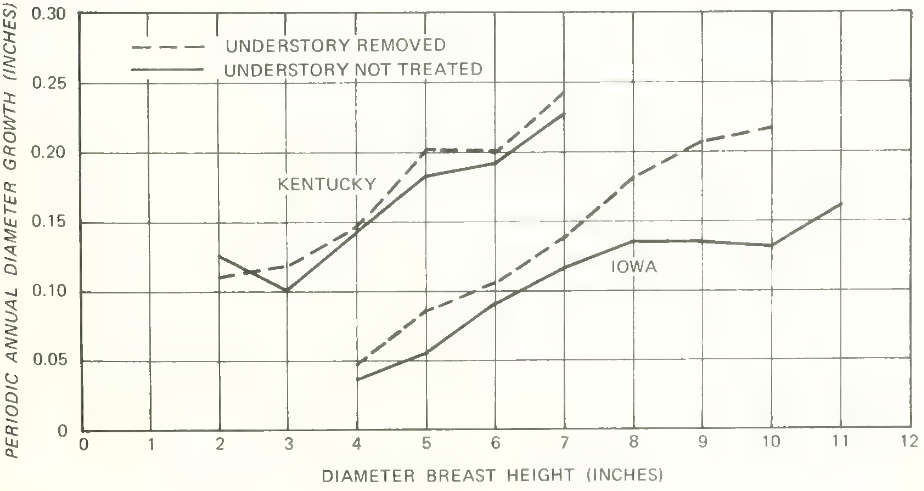
Table 6.—Mean annual periodic diameter growth of all surviving black oak trees by dbh class at age 20 for treated and untreated understory, in inches per year

Dbh class (inches)	Residual stocking percent					
	30		50		70	
	Treated	Not treated	Treated	Not treated	Treated	Not treated
2	0.23	—	0.12	0.12	0.09	0.07
3	.25	0.20	.15	.12	.13	.09
4	.29	.23	.20	.14	.17	.11
5	.33	.26	.23	.16	.21	.14
6	.32	.27	.26	.20	.24	.17
7	.37	.27	.27	.20	.23	.19
8	—	.29	—	—	—	.21
All trees	0.287	0.247	0.182	0.152	0.139	0.121

Table 7.—Mean annual periodic diameter growth of all surviving black oak trees by dbh class at age 40 for treated and untreated understory, in inches

Dbh class (inches)	Residual stocking percent					
	30		50		70	
	Treated	Not treated	Treated	Not treated	Treated	Not treated
5	0.15	0.18	0.14	—	0.08	—
6	.18	.22	.19	0.13	.08	0.09
7	.14	.22	.16	.12	.13	.10
8	.24	.24	.16	.16	.12	.11
9	.28	.23	.16	.15	.13	.11
10	.28	.22	.19	.15	.14	.13
11	.28	—	.14	.20	.20	.14
12	—	—	.17	.22	.19	.14
13	—	—	.17	.22	—	.15
All trees	0.202	0.223	0.170	0.143	0.116	0.114

Figure 1.—Periodic annual diameter growth of white oak in Kentucky and Iowa, by diameter class.



inch on the untreated plots. This is an average increase in diameter growth of about 22 percent due to removal of understory vegetation.

Individual white oak trees grew faster in Kentucky than in Iowa, but this was partially because the residual stocking was lower. All plots were thinned to about 37 percent stocking in Kentucky, and in Iowa stocking ranged between 50 and 90 percent and averaged 70 percent. Growth of individual trees in Iowa increased as stocking percentage decreased.

DISCUSSION AND RECOMMENDATIONS

Our results indicate that growth in some stands may be increased by nearly one-third if a dense hardwood understory is eliminated; but for other stands in the upland oak type, we may expect only slight, if any, growth increase. The most important factors that determine growth increase seem to be (1) geographical stand location, (2) stand age, and (3) residual stocking after the initial thinning.

Stands located in the western part of the upland oak region gave the greatest growth response when the understory was eliminated. The key to the amount of growth response is probably the availability of soil moisture for growth, which depends upon precipitation and soil properties, as well as temperature, relative humidity, and other factors.

Zahner (*1958*) found that soil moisture may be depleted 25 percent faster in pine stands with hardwoods left in place as compared to stands with hardwoods removed.

Precipitation, particularly during the critical spring and summer growth period, is usually less in the western part of the oak region. Ozark forest soils also are typically shallow and rocky and have a limited capacity for storing moisture, so summer drought conditions are more frequent and of longer duration than are conditions further east. More favorable soil-moisture conditions could be the reason why we found only a slight growth increase or none at all for the stands in Kentucky and Ohio. Karnig and Stout (*1969*) reported only a slight growth increase due to understory removal for a 70-year-old red oak stand in New York.

Similar studies in pine stands have shown that growth response due to understory removal of hardwoods was greatest in Arkansas and Missouri (*Grano,* 1970; *Bower and Ferguson, 1968; Rogers and Brinkman, 1965).* In contrast, studies of loblolly pine in Louisiana *(Russell, 1961)* and in South Carolina *(McClay, 1955); Klawitter, 1966)* failed to show any growth improvement after the hardwood understory was controlled.

Overstory thinning and understory removal both tend to decrease the competition for the available soil moisture and other growth factors. Growth of individual trees was greatest at the very lowest stocking levels (30-percent stocking); however, the increase in stand growth was greatest with about 50-percent residual stocking or at about the stocking level required for full site utilization. At the lower stocking, there are too few trees to fully occupy the area; but at about 50-percent stocking, the crown canopy is nearly closed. Areas devoid of trees at the lower densities are quickly filled in by understory vegetation; but as stocking increases above 50 percent, the understory competition is reduced, and overstory competition for growth controlling factors intensifies. Hence, the effect on growth of understory removal at the higher stocking levels is less, simply because the understory is too sparse to offer much competition.

Young stands respond more to understory removal treatments than older stands, probably because in young stands the understory is more dense and young trees respond quicker to environmental changes. Many understory stems live through the brush stage into the sapling or small pole stage because overstory competition is not as intense or not of long enough duration to completely kill them.

Would it be wise for timber managers to recommend understory removal treatments as a silvicultural practice in upland oak stands? We lack some of the cost and return data needed to evaluate this alternative; but judging by 10-year growth response of our plots and some reasonable assumptions on treatment costs and expected returns, we feel that the answer in most cases is no. The expected growth increase would very likely be small, usually amounting to less than 1 cord and seldom more than 2 cords in 10 years. If we assume that it costs $8.00 per acre to eliminate understory vegetation, the amortized cost of this treatment for 10 years at 6-percent interest would be $14.33. In most cases, the stumpage value of the extra cord or two of yield would be less than this amortized cost. Individual trees might average 0.1 or 0.2 inch larger in diameter 10 years after treatment than where the understory trees were left in place. Such a small amount of additional growth does not seem to justify the expense of removing the understory vegetation.

Besides the small growth increase and the high treatment cost, additional arguments can be presented that favor leaving the understory in place. Dense hardwood understories provide both food and cover for many wildlife species. For deer habitat purposes, Halls (*1973*) discouraged the practice of spraying herbicides to control hardwood understories in southern pine stands. Possibly the understory is just as important to wildlife-habitat management in upland oak as in pine.

Quality of overstory trees could be affected by understory removal. Shade from a dense understory, 15 to 20 feet in height, might help prevent epicormic branches from developing or might aid in earlier natural pruning of branches on the lower boles. However, the influence of understory vegetation on quality of overstory trees has not been studied.

CONCLUSIONS

Several long-term studies in upland oak stands show that growth may be increased nearly one-third by eliminating a dense hardwood understory, but in other stands there is only a slight growth increase or no growth increase. The largest growth response occurs in very young stands in the western part of the oak range where residual overstory stocking is reduced by thinning to about 50 percent. For most of the upland oak stands in the region, understory control does not seem to be a very profitable forestry practice because of (1) the small growth advantage, (2) the cost of understory treatment, and (3) the possibility of adverse effects on wildlife habitat.

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Analysis of the Campground Market in the Northeast

Report III

A PERSPECTIVE ON THE CAMPING-INVOLVEMENT CYCLE

by Marvin W. Kottke
Malcolm I. Bevins
Gerald L. Cole
Kenneth J. Hock
Wilbur F. LaPage

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F. BRYAN CLARK, STATION DIRECTOR

FOREWORD

THE NORTHEASTERN Regional Research Project NEM-42 was organized to conduct an economic analysis of the campground market in the Northeast. One of its four major objectives was:

> *To determine the motivations, goals, and characteristics of the camping public as a guide to development of a rational pricing system of public and private camping resource mix.*

This report presents the results of a nationwide household survey that was designed to meet this objective. The geographical scope of the survey was extended beyond the 12 Northeastern States to develop a comprehensive view of the camping market on a nationwide basis. This survey was designed by the NEM-42 Committee to learn more about the camping involvement cycle — from potential, to active, to inactive camping status — and to describe the images of camping at each stage of that cycle.

This is the third report prepared by the committee. Report I, *Analysis of the Campground Market in the Northeast: Public Policy (Bond et al. 1973)* deals with the legal authority and policies underlying management of public campgrounds. *Analysis of the Campground Market in the Northeast: Report II: Privately Owned Areas (Bevins et al. 1974),* presents the results of a survey of commercial camping operations.

This research was funded by the agricultural experiment stations at state universities of the 12 Northeastern States, and by the Family Camping Federation of America, the Chrysler Corporation, Kampgrounds of America, the Woodall Publishing Company, the National Sporting Goods Association, and the U.S. Forest Service.

The household interviews for this survey were conducted by the Opinion Research Corporation of Princeton, New Jersey, during November and December 1973.

The authors express their appreciation to Prof. Robert S. Bond, University of Massachusetts, Prof. Tommy L. Brown, Cornell University, and Prof. A. Robert Koch, Rutgers University, for their critical review and constructive help on this report.

A PERSPECTIVE ON THE CAMPING-INVOLVEMENT CYCLE

Results of a 1973 Nationwide Household Survey

A report by the Technical Committee of
Northeastern Regional Research Project NEM-42

"Economic Analysis of the Campground Market
in the Northeast"

ADMINISTRATIVE ADVISER

Earl F. Patric, Associate Director
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University of Rhode Island

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ABSTRACT

This is a report on a survey of 2,213 households and their potential for entering the camping market in 1973. One out of every two households was found to be in one of three stages of the camping-involvement cycle. Active campers included 21 percent of the sample, up by 2 percent since 1971; inactive campers, 20 percent, up by 6 percent; and potential campers, 9 percent, down by 2 percent. Reasons for the increased numbers of inactive campers, and possible barriers between potential and active participation, are examined in detail. Twelve separate components of the popular image of camping — environments, conditions, and attractions — are examined for each stage of the camping-involvement cycle.

INTRODUCTION AND PROCEDURE

The Problem

During the past 10 years, dozens of surveys of visitors to the Nation's 8,700 commercial camping parks and 6,500 public campgrounds have produced volumes of descriptive data about campers, their equipment, their likes and dislikes, their participation patterns, their travel habits, and their socioeconomic characteristics. A recent bibliography of camping-market research identifies more than 200 surveys and observational studies of campers *(LaPage and Haaland 1974)*. Because of their focus on known campers (usually at the campground), the majority of these surveys have had limited usefulness for:

1. Improving our understanding of camping market growth.
2. Designing marketing strategies that will effectively eliminate possible barriers to participation among potential campers.
3. Identifying the causes of a lack of camping by former campers.

Even a highly refined descriptive profile of active campers is not likely to provide reliable marketing clues for reaching the potential camper who needs specific information more than he needs a convincing appeal to try camping. And though surveys of active campers may include some who have temporarily stopped camping in the past, they have rarely attempted to examine the causes and control of camping market drop-out.

An earlier phase of this NEM-42 Project demonstrated that a relationship between marketing effort and commercial campground success exists and indicated a generalized need for an increased volume of business at most commercial campgrounds *(Bevins et al. 1974)*. Given effective market ing tools, it should be possible to attract new campers and influence the return-visitation patterns of ex-campers. The purpose of this research is to provide information that will lead to more effective marketing and improve camper satisfaction. The approach used in this study incorporates three major innovations in descriptive camper-survey research:

1. A comparison of the *images of camping* held by potential campers, active and inactive campers, and persons having little or no interest in camping.
2. An examination of those householders who were *almost a camper* at some time in the past, their consideration given to camping, and their reasons for not camping.
3. An evaluation of *the last camping trip,* its satisfactions and its disappointments for currently active campers, and for those who have given up camping temporarily or permanently.

Sample Selection

A representative national sample of 2,213 heads of households, interviewed by Opinion Research Corporation as a part of their December 1973 Caravan survey, provided the data for this study. To facilitate measurement of trends in growth of the camping market, the survey procedures were made comparable to those of an earlier study of the National Camping Market *(LaPage 1973)*. In the following analyses, segments of the sample have been weighted to accurately reflect current population statistics (table 1).

Table 1.—Demographic description of the national sample of households

Description	Percent of sample households	
	Before weighting	After weighting[1]
Men	49	49
Women	51	51
18–29 years of age	27	27
30–39	19	17
40–49	15	19
50–59	15	17
60 years or over	15	20
Less than high school	34	41
High school	34	37
Some college	31	22
Professional occupation	13	11
Managerial	12	11
Clerical, sales	10	11
Craftsman, foreman	19	21
Other manual, service	21	24
Farmer, farm laborer	3	3
Non-metro — rural	14	14
— urban	14	14
Metro — 50 M to 1 Million	29	27
— over 1 million	43	45
Northeastern U.S.	23	24
North Central	28	29
South	33	32
West	16	16
White	90	87
Non-white	8	11
Under $5,000 family income	17	22
$5,000 to $6,999	12	13
$7,000 to $9,999	19	20
$10,000 to $14,999	25	25
$15,000 or over	25	19
No children in household	50	50
Children under 18	50	50
Teenagers, 12–17	23	27
Home owners	69	65
Home renters	30	34

[1] Weighting was performed to reflect current population statistics.

On the basis of response to a pictorial question asking, "Have you ever gone on an overnight trip using any of these types of equipment?", households were classified as being either *campers* or *non-campers*. Campers were further classified as *active, temporarily inactive*, or *permanently inactive*. Active campers, those who went camping in 1973, included 21 percent of the weighted sample (table 2). Campers who had not been camping since 1970 or earlier, and who reported no intention of returning to an active camping status, made up 11 percent of the sample. Another 9 percent was classified as temporarily inactive, and was made up of campers who had not camped in 1973; however, most of them had camped in 1971 or 1972. One out of every two persons ever having camped was an inactive camper in 1973.

Table 2.—Extent of camping involvement by sample respondents, 1973

Camping-involvement group[1]	Percent of sample households	
	Before weighting	After weighting[2]
Campers:	43	41
Active	20	21
Temporarily inactive	10	9
Permanently inactive	13	11
Non-campers:	57	59
High potential	1	1
Medium potential	9	8
Low potential	16	17
Zero potential	32	33

[1] Definitions:

Active. Participated in camping in 1973.

Temporarily inactive. Had camped before, but not in 1973 and, if had not camped since 1970, specifically stated, "have not stopped camping."

Permanently inactive. Has camped, but not since 1970 and did not specifically state "have not stopped."

High potential. Never camped, but expected to camp in 1974.

Medium potential. Never camped, but expected to camp in future but probably not in 1974.

Low potential. Never camped and felt it would be unlikely in the foreseeable future, or didn't know.

Zero potential. Never camped and was definitely not interested.

[2] Weighting was performed to reflect current population statistics.

Non-campers, or nearly 60 percent of the sample, were further classified according to their potential for becoming campers in the near future. One percent of the total sample had made plans to try camping for the first time in 1974; these households were classified as having a *high potential* for entering the camping market. Another 8 percent of the total expressed a desire to try camping, but had not planned to do so in 1974, and were considered to have *medium potential.* Seventeen percent of the sample, the *low potential* group, stated that they were unlikely to try camping in the foreseeable future. And a *zero potential* classification was applied to the remaining one-third of the sample who were definitely not interested in camping.

The Camping-Involvement Cycle

A comparison of the results of this and the 1971 survey (table 3) reinforces the need, by all segments of the camping industry, for a better understanding of the three stages of the camping involvement cycle—from being a potential camper (high or medium potential), an active camper, or an inactive member of the camping market. [Inactive campers do continue to buy camping equipment *(LaPage and Ragain 1974)*]. According to our 1974 survey results, 9 percent of American households were potential campers, 21 percent active, and 20 percent inactive. The other 50 percent had little or no interest in camping.

Table 3.—A comparison of camping-involvement trends from 1971 to 1973

Involvement in camping	Number of households[1] 1971	1973	Change
	Thousands	Thousands	Percent
Active	12,600	14,300	+13
Inactive	9,100	13,600	+49
Potential[2]	7,400	6,100	−18
Little or no interest[3]	35,900	34,000	− 5
Total	65,000	68,000	+ 4
	Number of households		
Basis: (sample size)[4]	2,003	2,213	—

[1] Source of total households for the years 1971 and 1973: U.S. Census Bureau 1962. For converting households to persons, multiply by 3.11 for 1971 and by 3.01 for 1973.

[2] Includes high- and medium-potential groups.

[3] Includes low- and zero-potential groups, which are considered as not being in the camping-involvement cycle.

[4] Sampling errors for surveys in this size range are approximately 2 percent, or roughly 1.3 million households, at the 95 percent probability level. This means that only the inactive camper segment shows a difference between these two surveys, which could not be explained on the basis of sampling error alone.

The significant increase since 1971 in the size of the inactive segment of the market, combined with a shrinking reservoir of potential campers, indicates the emerging need for a totally new approach to the marketing of camping. The bulk of future market growth cannot continue to come from induction of initiates. Future growth will depend increasingly on higher levels of active participation and renewed interest by camping market drop-outs.

The increase in the ratio of inactive campers to active campers, from 3:4 in 1971 to 1:1 in 1973, suggests that current marketing practices may be highly successful in attracting new campers, but apparently are insufficient to hold them in the market or to reactivate former campers. The proportion of campers with at least 2 years of experience, who reported that their annual participation has been declining, was 50 percent in 1973; up from 37 percent in 1971.

The degree of difficulty of the marketing function increases as the size of the potential camping market decreases. In the early days of camping market expansion, family camping was an easy concept to sell. Willing buyers made the marketing job almost unnecessary. But, as thousands of eager potential campers swelled the demand, there occurred simultaneous increases in: (1) *consumer confusion* between hundreds of brand names and thousands of potential places to go camping; (2) *campground crowding,* waiting lines, and deterioration of facilities, resulting in a slipping image through camping's most effective advertising medium: word-of-mouth recommendations; (3) *rising costs* of camping and camping equipment, and direct comparisons with alternative forms of vacation travel, forcing camping to lose its once highly competitive edge; and (4) *diversity in camping motivations,* with resultant decreases in camping satisfactions and in camping's status appeal.

Today's marketing job is to overcome the liabilities developed as a result of earlier rapid expansion in the market. Three critical points of attack are developed in the following sections of this report: (1) the images of camping; (2) the transition from potential to active camper; and (3) recollections of the last camping trip. In each section, comparisons are made between the involvement categories as defined in table 2. Such comparisons have only tentative transient validity as people pass from one stage of the involvement cycle to another. Nevertheless, expressions by the respondents on their intentions for the future and their evaluations of past experiences are indicative of general market conditions.

THE IMAGES OF CAMPING

The rapid growth of the campground industry brought with it consumer confusion, crowding, rising costs, and diversity of motivations. Consequently, negative images of camping may be developing. Perhaps such negative images are contributing to a slowing-down of the camping growth rate. The first objective for this study was:

> *To compare the images of camping held by potential, active, and inactive campers with those held by non-campers and to evaluate the probable impact of the comparative images of camping growth rates.*

The following statement was used by the interviewers to aid respondents in providing a description of their camping images:

> "This exhibit contains descriptive words which can be used to describe camping. As I read the letter before the descriptive word, please choose a point on the scale which is closest to what would describe your impression of camping."

Respondents were told to choose a point on a scale ranging from 1 to 5 (1 = interesting to 5 = boring). The descriptive terms were randomly assigned so that the most positive term was not always listed first. For analysis purposes, rankings of both "3" and "no response" were considered to be the same reaction, since both responses indicate indifference.

Three components of the public's image of camping are recognized: camping environment, camping conditions, and camping attractions. The first component, *camping environment,* included the following four descriptive extremes: camping is interesting or boring; refreshing or tiring; pleasant or unpleasant; and campers are friendly or unfriendly. Each of these attitudes reflect a respondent's impressions of the physical and social environment of camping.

The second component, *camping conditions,* included the following four descriptive extremes: the campground is clean or dirty; safe or dangerous; uncrowded or crowded; and inexpensive or expensive. These attitudes are also logically grouped together because each is a direct function of campground management.

The third component, *the attraction of camping,* included the following four descriptive extremes: camping is easy or difficult; fun or work; convenient or inconvenient; and comfortable or uncomfortable. These terms reflect the camping activity itself, independent of physical and managerial considerations.

The Positive Camping Image

Considering the three components, or clusters of attitudes, we found that the most positive response from all groups related to *the camping environment* (table 4). More than half of all households (U.S. public) held positive attitudes about the camping environment. For the most part, they pictured a campground as interesting, the people friendly, and the experience as refreshing and pleasant. Such an image was most pronounced for active campers (80 percent), followed by the temporarily inactive (72 percent) and the permanently inactive (61 percent). The environmental images of the

Table 4.—Households holding a positive camping image classified by degree of camping involvement

Image description	Camping-involvement group					
	All	Active	Temporarily inactive	Permanently inactive	High and medium potential	Low and zero potential
	— — — — — — — *Percent of respondents* — — — — — — —					
Camping Environment:						
Interesting	55*	86	79	65	83	30
People friendly	59	78	66	69	64	47
Refreshing	44	73	70	47	62	21
Pleasant	52	81	73	63	81	27
Composite	52	80	72	61	72	31
Camping Conditions:						
Clean	34	54	39	40	47	21
Safe	43	64	60	45	45	30
Uncrowded	25	29	26	36	35	19
Inexpensive	37	50	44	41	40	28
Composite	35	49	42	40	42	24
Attraction of Camping:						
Easy	35	56	47	36	50	21
Fun	40	62	56	45	57	23
Convenient	27	47	40	31	35	15
Comfortable	39	65	56	43	54	20
Composite	35	58	50	39	49	20
Basis:						
number of respondents	2,199	450	214	281	198	1,056

* 55 percent of the U.S. public felt that camping was interesting, that is, they assigned a 1 or 2 rank on a 1 to 5 scale (1 being the most positive, 5 being the most negative).

high- and medium-potential campers closely resembled those of the temporarily inactive. Less than ⅓ of the low- and zero-potential group had a positive image of the camping environment.

Thirty-five percent of all households held a favorable image of *camping conditions*, by perceiving campgrounds as clean, safe, uncrowded, and not expensive. Active campers had the highest positive image (49 percent) of campground conditions. The temporarily inactive and permanently inactive campers had similar impressions of camping conditions: about 40 percent favorable. And about 40 percent of the high and medium potential campers had a good impression of camping conditions. Less than a quarter of those with low or zero potential had a positive image of camping conditions.

Like the image of camping conditions, 35 percent of the public had a positive image of *the attraction of camping* (easy, fun, convenient, and comfortable). Fifty-eight percent of the active campers, 50 percent of the temporarily inactive campers, and 39 percent of the permanently inactive campers had positive images of camping's attraction. The attraction for potential campers was as favorable as that of the temporarily inactive group, while the low- and zero-potential group were far below all others, only one out of five finding anything attractive about camping.

The Negative Camping Image

Camping's potential for expansion is also related to negative aspects of its image. A reversal of the positive image would be expected except that many people are indifferent and hold neither positive nor negative views. A stronger similarity was noted between permanently inactive campers and households with a little or no potential for camping (table 5). This similarity was not quite as evident when only the positive camping image was analyzed.

Of the three major components, the attrac-

Table 5.—Households holding a negative camping image classified by degree of camping involvement

Image description	Camping-involvement group					
	All	Active	Temporarily inactive	Permanently inactive	High and medium potential	Low and zero potential
	Percent of respondents					
Camping Environment:						
Boring	19*	6	10	15	3	30
People unfriendly	11	11	16	10	17	3
Tiring	25	10	18	28	15	35
Unpleasant	18	8	13	15	7	26
Composite	18	9	14	17	10	24
Camping Conditions:						
Dirty	22	15	17	23	15	26
Dangerous	15	9	10	17	21	16
Crowded	32	32	35	38	35	29
Expensive	18	15	17	19	21	18
Composite	22	18	20	24	23	22
Attraction of Camping:						
Difficult	25	13	24	30	22	29
Work	26	18	21	26	18	32
Inconvenient	33	19	24	36	26	40
Uncomfortable	26	11	18	28	12	35
Composite	28	15	22	30	20	34
Basis:						
number of respondents	2,199	450	214	281	198	1,056

*19 percent of the U.S. public felt that camping was boring, that is, they assigned a 4 or 5 rank on a 1 to 5 scale (1 being the most positive, 5 being the most negative).

tion of camping was most likely to be negative (camping is difficult, work, not convenient, and uncomfortable) for all except active and potential campers. This suggests a major barrier to market expansion because attraction should be stronger in order to overcome the correctable negative images of environment and camping conditions.

Looking at specific elements of the negative image, we found that about 1 out of 10 active and temporarily inactive campers see camping as being dangerous. However, 25 percent of the high-potential group and 20 percent of the medium-potential group include an element of danger in their image of camping. The most common image of camping conditions, held by 1 out of 3 campers and noncampers alike, is crowding. This seems to provide the most obvious focus for attempts to improve the public image of camping conditions.

The Indifferent or Moderate Image

While it is important to analyze both positive and negative images, the indifferent or undeveloped opinion about camping may also suggest marketing opportunities. Nonresponse to image elements was minimal in all groups except for those with low or zero potential, where the nonresponse was nearly as great as the indifferent response.

The frequency of indifferent images ranged from 29 percent for the camping environment to 44 percent for camping conditions, and the percentages were surprisingly similar for active, temporarily inactive, and potential campers. These relatively high frequencies may indicate a reluctance to generalize about situations that can be both favorable and unfavorable (table 6). However, when the indifferent image is combined with the negative image for factors such as crowding, convenience, and cleanliness, it becomes apparent that the industry faces a major challenge to produce a more desirable image and thereby expand the potential for market growth.

An Image Index Related to Demographic and Camping-Involvement Groups

To evaluate either the positive or negative camping image alone could lead to distorted impressions. A composite image index was devised by dividing the percentage of households holding a positive image by those holding a negative image. (The indifferent or moderate image is excluded from this image index.) A single index number is derived for each group of households (active campers, Westerners, home-owners, etc.) by averaging the 12 image factors.

Image indices ranged from slightly below 1.0 to slightly above 4.0; that is, for each person having a negative impression of camping, there were between 1 and 4 persons having a favorable impression. The only group having an image-index of less than 1.0 was that of households having little or no potential to enter the camping market. The image-index for the general public is 1.7, while that for active campers is 4.3 (that is 4.3 favorable for each unfavorable).

The image index provides a tool for studying the camping potential of various demographic groups. Potential campers have an index of 2.6. Others approaching this level are heads of households who are 18 to 29 years old (2.6), home renters (2.1), and Westerners (2.2). At the other extreme, the lowest image-indices are found among: farmers

Table 6.—Households holding an indifferent or moderate camping image, classified by degree of camping involvement

Image description	Camping-involvement group					
	All	Active	Temporarily inactive	Permanently inactive	High and medium potential	Low and zero potential
			Percent of respondents			
Camping Environment:						
Interesting-boring	26*	8	11	20	14	40
People friendly-unfriendly	30	11	18	21	19	45
Refreshing-tiring	31	17	12	25	23	44
Pleasant-unpleasant	30	11	14	22	12	46
Composite	29	12	14	22	17	44
Camping Conditions:						
Clean-dirty	44	31	44	37	38	53
Safe-dangerous	42	27	30	38	34	54
Uncrowded-crowded	43	39	39	26	30	52
Inexpensive-expensive	45	35	39	40	38	54
Composite	44	33	38	35	35	53
Attraction of Camping:						
Easy-difficult	40	31	29	34	28	50
Fun-work	34	20	23	29	25	45
Convenient-inconvenient	40	34	36	33	39	45
Comfortable-uncomfortable	35	24	26	29	34	44
Composite	37	27	28	31	32	46
Basis:						
number of respondents	2,199	450	214	281	198	1,056

*26 percent of the U.S. public were indifferent or had a moderate view on whether camping was boring or interesting, that is, they assigned a 3 rank or failed to respond to the question.

(1.2), persons over 60 years old (1.3), Northeasterners (1.3), and women (1.4) (appendix VI).

In terms of education there was relatively little difference between groups. The image index of farmers, clerical, and sales workers was considerably lower than that of craftsmen and foremen. Those with an annual income less than $7,000 had a higher image index than families in higher income groups, especially those whose incomes exceeded $15,000.

To validate the image index, a similar analysis was made of responses to the following open-ended question:

> "As briefly as possible, tell me what thoughts come to mind as you think about living at a campground for a few days."

Disregarding the nonresponse and the irrelevant answers, all responses containing a positive statement were divided by all within that group making a negative statement, to create a second image index. For the most part, the same general relationships between population groups were found. However, the spread between income groups was less, and the relative positions of certain income groups changed from the preceding analysis. Also, the spread between home-renters and homeowners was reduced. A slightly larger spread between the residents of large metropolitan areas and smaller urban area was noted. However, all factors considered, the validity of the image index is substantiated.

Attitude Toward Cost of Camping

One element of the camping image—"camping is expensive or not expensive"—was assumed to be a major potential barrier to market growth. Respondents were asked to consider the total cost of camping, including taxes on equipment, campsite fees, extra tolls, insurance, and equipment costs, and decide whether camping is more economical than other ways of traveling and taking a vacation (table 7).

Two-thirds of all active campers felt that camping was more economical than alternative ways of vacationing. This attitude was far more prevalent among active campers than among any other group, including those households with a high potential to try camping. One-third of the high-potential respondents felt that the cost of camping was about the same as other ways of traveling and taking a vacation. The cost-image of camping, among potential campers, is clearly not one of "bargain basement travel." And the apparent advantage seen by active campers may be as much a justification of their equipment investment as it is a reflection of their superior knowledge of the market.

Table 7.—Attitudes toward the total cost of camping as compared with other ways of traveling and taking a vacation, in percent[1]

Camping-involvement group	More economical	Less economical	About same	Don't know
U.S. public	43	14	19	24
Active campers	66	13	17	4
Temporarily inactive	51	18	27	4
Permanently inactive	45	18	24	13
High-potential households	51	15	34	0
Medium-potential households	53	9	24	14
Low-potential households	36	16	18	30
Zero-potential households	27	11	17	47

[1] Respondents were asked to visualize the total cost of camping as including taxes on equipment, campsite fees, extra tolls, insurance, and other equipment costs.

ALMOST A CAMPER

With 10 percent of the population as potential campers, those households that are almost in the camping market become an important focus for research. What has kept them from taking that first camping trip? What types of equipment are they likely to use if they decide to try camping? What other kinds of recreational activities are they interested in?

The second objective of this study—*to determine the processes by which people move from the reservoir of potential campers to become active members of the camping market*—is approached through a comparison of campers, potential campers, and persons with little or no interest in camping.

Characteristics of Potential and Nonmarket Households

Potential includes both high- and medium-potential groups. The *Nonmarket* includes those households that are considered to have low or zero potential for entering the camping market.

We hypothesized that many potential entrants would be young families with children and that their interest is prompted primarily by a search for low-cost recreation.

In comparing the socioeconomic characteristics of potential campers with the characteristics of the nonmarket households, we saw several patterns emerge (table 8). Potential campers are more numerous in the 30 to 49-year age bracket than are active campers. Nearly half of the active camper group are under 30. Persons 50 and over are not as likely to be interested in camping as those in younger age groups. And potential campers are much more likely to have children in the household than are the nonmarket households and the active campers (table 9).

Nearly one-half of the potential campers reported 1973 incomes of $10,000 or more (table 10). The largest income category among nonmarket households was less than $5,000.

More than 19 percent of the potential campers were nonwhites, compared to 3 percent of all the active campers and 11 percent of all households (table 11).

Region of residence seems to influence the market for potential campers. The Northeast has the greatest proportion of potential campers and the smallest proportion of active campers (table 12). This may be due in part to the historical development of fewer public campsites per capita in these regions than in the North Central or Western regions *(ORRRC 1962)*. As a result of having more camping opportunity, a larger proportion of

Table 8.—Age category distributions for all households and selected camping market segments (1973), in percent

Age category (years)	All households	Active campers	Potential campers	Nonmarket households
18–29	27	46	36	16
30–39	17	21	27	14
40–49	19	14	24	20
50–59	17	12	9	19
60 and over	20	7	4	31
Total	100	100	100	100

Table 9.—Presence of children for all households and selected camping market segments, 1973, in percent

Children in household	All households	Active campers	Potential campers	Nonmarket households
Yes, under 18 years of age	50	58	78	42
None	50	42	22	58
Total	100	100	100	100

Table 10.—Income classes for all households and selected camping market segments, 1973, in percent

Income level (dollars)	All households	Active campers	Potential campers	Nonmarket households
Under 5,000	22	15	18	27
5,000–6,999	13	11	16	14
7,000–9,999	20	20	19	20
10,000–14,999	25	28	28	22
15,000 and over	19	26	19	16
Total	99	100	100	99

Table 11.—Race breakdown of all households and selected camping market segments, 1973, in percent

Race	All households	Active campers	Potential campers	Nonmarket households
White	87	97	78	82
Nonwhite	11	3	19	17
Total	98	100	97	99

the North Central or Western population has already tried camping.

Table 12.—Region of residence for all households and selected camping market segments, 1973, in percent

Region of residence	All households	Active campers	Potential campers	Nonmarket households
Northeast	24	14	34	29
North Central	28	23	18	32
South	32	31	36	31
West	16	32	12	8
Total	100	100	100	100

Table 13.—Friends owning camping equipment, by camping-involvement group, in percent

Camping-involvement group	Friends owning equipment		
	Yes	No	Don't know
Campers:			
Active	94	6	0
Temporarily inactive	90	10	0
Permanently inactive	77	21	2
Potential campers:			
High potential	76	24	0
Medium potential	67	32	1
Nonmarket households:			
Low potential	46	51	3
Zero potential	31	61	8
All groups	60	36	4

Table 14.—Respondents having visited a camping or recreational-vehicle show within past two years, 1973

Camping-involvement group	Visited camping show
	Percent
Campers:	
Active	51
Temporarily inactive	34
Permanently inactive	22
Potential campers:	
High potential	25
Medium potential	26
Nonmarket households:	
Low potential	14
Zero potential	6
Total	23

Association with Camping Friends

More than two-thirds of the potential campers have friends who own camping equipment, while less than one-half of the nonmarket households report associating with persons who are active or inactive campers (table 13).

The industry might, for example, examine marketing techniques that enhance the likelihood that campers will introduce noncampers to camping. For example, commercial campgrounds might sponsor occasional open houses or a free camping weekend for regular customers who bring along potential campers to inspect the campground and meet other campers. Or campgrounds having sites with equipment rentals might offer a discount rate in a rental unit during slack periods in the season for people who have never camped before.

Visits to Camping Shows

Visits to camping or recreational-vehicle shows are a partial indicator of potential camping interest. But only one out of four potential campers reported having visited a camping or recreational vehicle show during the previous 2 years (table 14). The strongest appeal of camping shows seems to be for the active and temporarily inactive campers.

Considering a Camping Trip

Three-fourths of the high-potential group and more than one-half (54 percent) of the medium-potential campers had considered going camping during the past 1 to 3 years (table 15). Of those having considered camping, one out of two had selected a region to visit, and one out of three had looked into the possibilities of buying, renting, or borrowing camping equipment for the trip.

Those who had considered camping were asked why they did not take the trip they had contemplated. The most frequent reason given by the high-potential group was the lack of sufficient time, followed by a lack of information about camping equipment. Other less

Table 15.—Noncamper households who have considered a camping trip, their extent of planning, and their reasons for not camping, in percent

Item	Camping-potential group				
	High	Medium	Low	Zero	Total
Non-camper households considering camping	75	54	13	2	14
EXTENT OF PLANNING TO CAMP[1]					
Selected a region to visit	77	48	54	50	50
a. Wrote for camping information[2]	23	15	8	0	14
b. Attempted to make reservations[2]	1	2	0	0	4
Checked into cost of camping equipment	51	37	31	0	36
Checked into cost of renting equipment	11	22	23	0	21
Checked into borrowing equipment	45	33	15	0	29
REASONS FOR NOT HAVING STARTED CAMPING[1]					
Cost of camping	6	19	19	33	21
Other priorities for time	33	14	19	0	14
Lack of equipment information	18	11	6	33	14
Lack of campground information	1	10	12	0	7
Uncertain of social enjoyment	6	3	6	0	7
Lack of equipment	6	6	*	0	7
Mixed preferences within family	0	2	6	0	*
Gas shortage	0	3	*	0	*
Other	30	32	32	34	30
Estimated number of households in each potential group (millions):	0.8	5.3	11.2	22.5	39.8

[1] Asked only of those who considered camping in the past 1 to 3 years.
[2] Asked only of those who had selected a region to visit.
* Signifies any value less than 0.5 percent.

frequent reasons included concern about the cost of camping, uncertainty about the experience of associating with other campers, and the lack of equipment. Among the medium-potential group, concern about the cost of camping was cited most often, followed by lack of time. Other reasons included lack of information about equipment and available campgrounds as well as the lack of equipment.

This reinforces our finding that the image of camping is complex. It shows a need for the industry to communicate with potential campers and satisfy their needs for information. Relevant information for prospective campers might include a cost-comparison of various types of equipment (for example, tents and associated equipment compared with self-contained trailer, truck, or motor home units) for different camping objectives, and expected frequencies of camping trips. Attempts at providing relevant information should have the objective of reducing the complexity that potential campers see in becoming involved with camping equipment and choosing among campground locations and facilities.

Of those who had previously considered a camping trip, about one-half of the high-potential group and one-third of the medium-potential group had investigated the cost of purchasing camping equipment. Almost the same respective proportions of the two groups had considered borrowing equipment for their first trip. Equipment rental was explored to a lesser extent by potential campers. Again, this suggests an opportunity for the campground industry to provide information about the alternative costs of equipment purchase versus rental.

Camping Shelter Likely to be Used

Tents are most likely to be chosen for the first camping trip by both the high- and medium-potential campers (table 16). In a distant second place, and at the opposite end of the cost spectrum, is the motor home.

Of the potential tent campers, 40 percent expect to purchase a tent for their first trip, while one out of three intends to borrow a tent, and 11 percent hope to rent a tent. Purchasing intentions among high-potential campers were more than three times that of the medium-potential group.

Nearly three-fourths of all potential campers who indicated camper trailers or travel trailers as their first choice are most likely to rent units for their first trip. Among potential campers who are likely to choose a motor home, 60 percent of those with high potential would prefer to purchase, and one out of two with medium potential expect to purchase.

Participation in Outdoor Recreation Activities

Potential campers are frequent participants in other outdoor recreation activities. An index of participation for 10 outdoor recreation activities shows that participation in activities other than camping increases as potential campers become active campers and diminishes as their camping declines (table 17). Those classified as disinterested (low and zero camping potential) participated least in other outdoor recreational activities. Thus camping activity may be a useful indicator of total outdoor recreational involvement by households.

Equipment Purchases

Another question asked was, "During the next year, which of the following types of equipment do you expect to purchase?" An index for 15 different kinds of outdoor-recreation equipment indicated that the interest in purchasing increases from medium- to high-potential camping groups. Expectations of buying equipment remain high among active campers, but decline slightly among temporarily inactive campers (table 18). The dis-

Table 16.—Type of shelter potential campers expect to use on first trip, in percent

Type of shelter	Camping-potential group	
	High	Medium
Tent	59	37
Motor home	10	17
Folding trailer	10	12
Truck camper	10	12
Travel trailer	3	12
Van or bus conversion	6	5
Pickup cover	2	2

Table 17.—Index of participation in ten outdoor recreation activities, by camping-involvement group, 1973

Camping-involvement stage and group	Index of participation in 10 recreation activities[1]
Medium potential	243
High potential	317
Active	385
Temporarily inactive	312
Permanently inactive	215
Low potential	145
Zero potential	89

[1] Obtained by adding the percentage of participation in each activity for the following 10 activities: picnicking, swimming, fishing, boating, hunting, hiking, trail-bike/snowmobiling, back-packing, canoeing, and snow skiing. See table 19 for participation rates by individual activities.

Table 18.—Index of expected outdoor-recreation equipment purchases, by camping-involvement group, 1973

Camping involvement	Index of expected equipment purchases[1]
Medium potential	99
High potential	246
Active	152
Temporarily inactive	125
Permanently inactive	60
Low potential	40
Zero potential	15

[1] Constructed by summing percentages for each sample group. See table 20 for listing of types of equipment.

interested group has a very low expectation of purchasing outdoor recreation equipment.

Obviously, interest in outdoor-recreation equipment is closely related to interest in camping. Marketing efforts for outdoor-recreation equipment aimed at persons with the characteristics of the active or high-potential campers would probably be most productive.

The importance of campers in the total demand for many types of outdoor-recreation facilities and equipment is clearly evident (appendix I and II). The three categories of campers made up 41 percent of the total survey sample and accounted for 52 to 55 percent of the picnicking and swimming, 62 to 69 percent of the motorboating, and 70 to 95 percent of the participation in the other activities listed. Campers may be expected to purchase 60 to 69 percent of the fishing and hunting equipment, snowmobiles, trail bikes, motor boats, and refrigerators or coolers; 70 to 79 percent of the hiking and skiing equipment, sleeping bags, camp stoves, and lanterns; and more than 80 percent of the planned lightweight tents, back-packs, and canoes.

THE LAST CAMPING TRIP

Does the high rate of camper drop-out represent normal attrition? Do people become involved over a period of years and then gradually quit camping? Is there a relationship between the camping-involvement cycle and the family life cycle? Is the accelerating rate of camping market drop-out since 1971 due, in part, to dissatisfaction with camping experiences? We hypothesized that impulsive entry into the market may have led to short-lived camping involvement for some who found that camping and campers were different from their expectations.

Our purpose in focusing on the last camping trip was to evaluate the satisfactions and disappointments of campers as they approach the inactive stages of the involvement cycle. Specifically, the objective for this part of the study was:

> *To evaluate the processes by which campers leave the camping market and to determine the extent and source of camper dissatisfactions.*

Campers are Different

To get an indication of how campers might differ from noncampers, respondents were asked about their participation in selected outdoor-recreation activities that may complement the camping activity. Campers are action-oriented people who commonly participate in many types of outdoor-recreation activities. Active and temporarily inactive campers are much more likely to be participants in outdoor activities other than camping (table 19). Active campers represent only 21 percent of the sample, but they account for more than half of the reported participation in backpacking, hiking, skiing, and trail-bike and snowmobile use (appendix I).

The idea that campers are a more active group of people is further supported by an examination of plans to purchase outdoor-recreation equipment (table 20). The percentage of active and temporarily inactive campers with plans to purchase various types of outdoor-recreation equipment in 1974 accounted for more than 50 percent of all expected purchases (appendix II). Purchase intentions were, expectedly, highest among the small group having high camping potential; and the similarity in purchasing plans be between active and temporarily inactive campers suggest that the temporary classification is a reasonably accurate one. The high proportion of temporarily inactive campers planning to purchase lightweight tents suggests that camping market dropout may be preceded by a search for alternative camping styles (table 20).

The reasons given by inactive campers for not having camped recently are predominantly personal constraints rather than a reaction to changes in the camping environment (table 21). The lack of equipment, affecting 1 out of every 10 inactive campers, seems to be the only limitation that the industry might be able to correct.

In response to the question about disposal of equipment by inactive campers, 40 percent of the temporarily inactive campers and 53 percent of the permanently inactive campers

Table 19.—Percentage of camping-market groups participating in selected recreation activities, by 1973

Recreation activity	Camper-involvement group					
	Little or no potential	Medium potential	High potential	Active	Temporarily inactive	Permanently inactive
Picnicking away from home	34	71	76	70	62	46
Swimming away from home	31	62	63	63	60	47
Fishing	21	39	53	65	55	39
Motorboating	11	25	32	49	37	32
Hiking	4	20	18	45	30	18
Hunting	6	10	41	34	31	12
Trail-bike/snowmobiling	2	7	13	22	14	10
Canoeing	2	5	14	12	13	10
Snow skiing	1	4	5	11	7	5
Back-packing	(*)	2	3	14	8	1
None of the above	37	9	8	3	8	18

* Less than 0.5 percent.

Table 20.—Percentage of camping-market groups expecting to purchase recreation equipment in 1974

Type of equipment	Little or no potential	Medium potential	High potential	Active	Temporarily inactive	Permanently inactive
Sleeping bags	2	15	46	23	18	8
Fishing	8	23	40	28	29	14
Hunting	3	11	27	14	16	7
Cooler/Refrigerator	3	10	23	15	12	6
Lantern	1	7	21	13	9	3
Camp stove	1	6	14	7	7	2
Lightweight tent	0	1	14	4	8	2
Hiking	(*)	3	11	6	2	2
Back-pack	1	2	11	8	5	2
Heater	1	5	10	5	2	2
Skiing (snow)	1	3	7	9	3	2
Motorboat	2	5	4	6	3	3
Trail-bike	2	5	2	7	4	4
Snowmobile	1	0	2	2	2	1
Canoe	1	0	0	3	1	(*)
Other	1	0	0	2	4	2
None of these	85	51	23	38	45	70

* Less than 0.5 percent.

Table 21.—Frequency with which inactive campers reported selective reasons for not having camped since their last trip, in percent

Reason	Temporarily inactive	Permanently inactive
Lack of time	31	24
Lack of money	13	8
Lack of equipment	12	9
Lack of interest	10	19
Family conflicts	9	10
Crowded and dirty campgrounds	—	4

reported that they never owned camping equipment. And 9 percent and 24 percent, respectively, have disposed of their equipment. On the basis of current equipment ownership, alone, only about 25 percent of all inactive campers might be encouraged to try camping again.

Campers' Satisfaction With Their Last Trip

One important measure of industry performance is customer satisfaction. The majority of campers in all camper groups expressed general satisfaction with the overall experience on their last camping trip (table 22). Only 7 percent of the active campers were generally dissatisfied with their last trip, as were 11 percent of the temporarily inactive campers. However, dissatisfaction with the last camping trip was reported by 27 percent of the permanently inactive campers.

Though a high proportion of campers were generally satisfied with their last trip, substantially fewer were pleased with the availability and quality of specific accommodations at the campgrounds they visited on that trip. In contrast to the 93 percent of the active campers who were satisfied with their overall trip, 73 to 78 percent were satisfied with the availability of campsites, recreation facilities, and the cleanliness or condition of the campgrounds visited. Dissatisfaction was most common for both active and inactive campers on: campground cleanliness (13 percent), recreation facilities (11 percent), and availability of campsites (11 percent).

Not all camping trips are carefully planned in advance. Thirty-nine percent of all active and inactive campers indicated that their last

Table 22.—Camper satisfaction with the last camping trip, in percent

Item and satisfaction	Active	Temporarily inactive	Permanently inactive	All campers
Overall trip:				
Generally satisfied	93	89	73	86
Generally dissatisfied	4	8	16	8
Does not apply to camping style	2	2	6	3
Campsite availability:				
Generally satisfied	78	75	63	72
Generally dissatisfied	9	12	13	11
Does not apply to camping style	12	11	18	14
Hookup availability:				
Generally satisfied	53	54	39	49
Generally dissatisfied	5	7	7	6
Does not apply to camping style	38	33	40	37
Recreation facilities				
Generally satisfied	73	71	55	67
Generally dissatisfied	11	12	14	11
Does not apply to camping style	15	15	24	18
Cleanliness and condition of campground:				
Generally satisfied	78	76	65	74
Generally dissatisfied	12	13	15	13
Does not apply to camping style	9	9	15	10

camping trip was taken with relatively little planning. However, the difference in percentages of active and inactive campers who camped on impulse is not great enough to indicate that unplanned trips were a cause of dissatisfaction leading to camping inactivity.

Use of a tent on the last trip was most common among all classes of campers, and was highest for the permanently inactive group. Nearly two-thirds of the inactive campers used tents or tent-trailers, while fewer than one out of five used motor homes, truck campers, or converted vans. Because the temporarily inactive camper represents a transition stage of involvement, a few of those currently using tents and tent-trailers may be in the market for unitized camping rigs (motor homes, trucks, and vans) (table 23).

Classification of campgrounds by type of ownership showed relatively little difference in utilization by each of the camper groups on their last camping trip. Approximately half of all active and inactive campers patronized publicly owned and operated campgrounds, one-fourth to one-third chose privately operated campgrounds, and 15 percent visited both types on their last trip.

Table 23.—Type of shelter used on the last camping trip, in percent[1]

Shelter	Camper group: Active	Temporarily inactive	Permanently inactive
Tent	41	46	49
Folding trailer	11	15	8
Travel trailer	17	18	20
Truck camper	15	9	6
Motor home	7	5	3
Van or converted bus	10	5	4
Pickup cover	5	5	3
Other	5	3	6
Unknown	1	2	3

[1] Percentages by camper group add to more than 100 percent because some respondents used more than one type of shelter.

Camping Fees

In addition to evaluating campground facilities, campers were asked about their satisfaction with the costs of camping encountered on their last trip. Seventy percent of the active and temporarily inactive campers expressed general satisfaction with fees paid for facilities on their last camping trip compared to 54 percent of the permanently inactive campers (table 24). But less than 10 percent of all campers were dissatisfied with the fees.

All campers and noncampers were asked whether fees charged at publicly operated campgrounds should be set high enough to cover all costs of developing and operating the facility or whether fees should be kept low by covering most of the costs with tax monies. A majority of active campers felt that fees should be kept low. However, the largest proportion of inactive and potential campers who expressed a definite opinion felt that camping fees should cover all costs of operating public campgrounds. Inactive campers felt most strongly that fees should cover costs—a further indication that cost was probably not a cause of inactivity. The lack of any opinion by large segments of the public having little or no potential for becoming campers tends to distort the true level of relevant public opinion that fees should cover all costs of operating public campgrounds (table 25).

Table 24.—Level of satisfaction with camping fees, in percent

Level of satisfaction	Camper group: Active	Temporarily inactive	Permanently inactive
Generally satisfied	70	70	54
Generally dissatisfied	9	8	5
Does not apply to camping style	17	16	25
Don’t know	4	6	16

Table 25.—Opinion of respondents concerning public campground fees, in percent

Sample group	Fees cover all costs	Fees kept low	No opinion
Active campers	43	51	6
Temporary inactive campers	56	37	7
Permanent inactive campers	49	34	17
High-potential campers	52	42	6
Medium-potential campers	48	45	7
Low-potential campers	36	30	34
Zero-potential campers	31	20	49
Total sample	40	34	26

Table 26.—Primary purpose for camping for active and inactive campers, in percent

Purpose	All campers	Active	Temporarily inactive	Permanently inactive
Vacation inexpensively	16	13	19	21
Enjoy out-of-doors	53	54	52	52
Both of above	25	32	23	18
No opinion	5	1	6	9
Total	100	100	100	100

Table 27.—Recent trends in camping participation for all campers having begun camping prior to 1973, in percent

Camper group	Trend		
	About the same each year	Increased lately	Decreased lately
All campers	20	16	50
Campers without children	20	13	51
Campers with children	20	18	48
Currently active campers	31	28	26
Head-of-household under 30	19	16	45
Head-of-household 30–39	21	22	45
Head-of-household 40–49	22	13	53
Head-of-household 50–59	20	13	56
Head-of-household 60 or older	13	12	60

Reasons for Camping

More than half of the respondents who had camped indicated that their primary purpose in camping was to enjoy the out-of-doors or outdoor activities. Only 16 percent went primarily as a means of vacationing inexpensively, and 26 percent said both reasons were important (table 26). However, a significantly (0.05 level) higher proportion of inactive campers went camping primarily as a means of vacationing inexpensively than did active campers. Hence, while economy in vacation expenditures was not the primary reason for camping among the majority of respondents, it does appear to have been relatively more important among those who are currently inactive.

The observation that camping seems to be related to life-cycle stages is reinforced by the stronger positive image of camping held by people having children in the household and by their higher incidence of having camped (44 vs. 38 percent) or having considered camping (21 vs. 7 percent). Apparently the presence of children in the household increases the likelihood of camping involvement. But once a household is in the camping market, life-cycle changes have no consistent effect on length of frequency of participation *(LaPage and Ragain 1974)*. Recent camping patterns among all campers indicate little or no relationship to the presence of children in the household (table 27).

SUMMARY AND CONCLUSIONS

As eager campers swelled demand during the 1960s, builders of campgrounds and suppliers of camping equipment responded by investing heavily in the industry. Recent declines in the growth rate of equipment sales and new campground developments, along with a sharp increase in numbers of inactive campers, seem to herald an era of new marketing challenges for the industry.

The purpose of this study was to investigate the reasons for the apparent decline in several of the camping industry's growth indicators. The approach used was to apply the concept of a camping-involvement cycle, with emphasis on explaining the processes of entry and exit of campers into and out of the cycle. A basic hypothesis of the study was that the popular image of camping had deteriorated for many campers and that disappointing camping experiences markedly increased exit rates.

The concept of a camping-involvement cycle assumes that there are stages through which people move as they become involved in and then eventually leave camping. Persons or households become potential campers, then active campers, and finally become ex-campers or camping market drop-outs.

According to our 1973 survey results, 9 percent of all U.S. households were in the potential stage, 21 percent were in the active stage, and 20 percent were either temporarily or permanently out of the market. The remaining 50 percent were not involved in any stage of the cycle. Not only is the reservoir of potential campers relatively small, it has decreased from 7.4 to 6.1 million households between 1971 and 1973. This change, plus the increase in drop-outs, emphasizes the need for an understanding of peoples' expectations, experiences, and images of camping.

Potential campers were classified as having *medium* or *high potential* based on their explicit plans to start camping. Inactive campers were classed as *temporarily inactive* or *permanently inactive,* depending upon their length of inactivity and their intentions of returning to an active status. These four groups, plus the active campers, account for one-half of all households. The other half was divided into households with *low* and *zero potential* for camping.

The first objective of this study was to compare the *images of camping* among the several camping-involvement groups. Respondents' images of camping were analyzed with reference to three components: the camping environment, the camping attraction, and camping conditions.

A high proportion (52 percent) of all respondents had a favorable impression of *the* camping environment. That is, most people viewed camping as friendly, pleasant, interesting, and refreshing. Only 18 percent had a negative image, and 29 percent had no specific impression of the camping environment.

Only 35 percent of all respondents held a positive image of camping conditions (clean, safe, uncrowded, inexpensive), while 44 percent had neither a favorable or unfavorable view of camping conditions. Among the negative impressions, crowding was viewed similarly at all stages of the camping-involvement cycle: one out of three respondents saw campgrounds as being crowded places.

The attractions of camping (ease, enjoyment, convenience, comfort), were recognized by 35 percent of all respondents. Of the three components of the camping image, attraction was most frequently seen to be negative (28 percent) by all respondents. Negative images of camping were based largely on the impression that camping is not convenient, is too much work, and is not very comfortable. This common view suggests that a trade-off between low-cost accomodations and inconvenience is not a consideration for many people who might otherwise be potential campers. Again, however, many respondents (37 percent) were indifferent or had an undeveloped image of the attractions of camping.

Active campers and high-potential campers had a much higher image of camping than did any other group. Next highest were the temporarily inactive and medium-potential campers, followed by the permanently inactive campers. The poorest images were held by the low- and zero-potential groups. Differences in the images of camping between the potential and inactive campers suggest that expectations of a rewarding camping experience were probably higher than the rewards actually experienced by those who later became inactive. In short, camping images tend to follow, and to reinforce, our description of the camping-involvement cycle.

The second objective of this study was to determine the processes by which people move from being *almost a camper* to becoming an active camper. The survey indicates that potential campers are mainly young families with children who are active in outdoor-recreation activities. More than 19 percent of the potential campers, compared to 11 percent of the total sample, were nonwhites. More than two-thirds of the potential campers had friends who own camping equipment.

Considerable geographic variation exists between regions of the country in numbers of potential campers. The Northeast and South have the highest proportions of potential additions to the market (34 and 37 percent, respectively, of all households). This corresponds only partially with camping images by regions. Southerners had a correspondingly high image, but the Northeastern respondents did not. Apparently factors other than image influence camping potential.

More than half of the potential campers had considered taking a camping trip in the past 1 to 3 years. However, very few had sought information about the availability of campgrounds and practically none had tried making reservations at a campground. Other priorities for time, followed by a lack of information about camping equipment, were reasons frequently given for not having started camping by those who had considered it. Fewer than one out of five people considering a camping trip had investigated the cost of camping equipment; and most potential campers excepted to purchase a tent for their first trip.

Intentions of purchasing a variety of outdoor-recreation equipment coincided with camping-market involvement stages. Similar findings from a study of actual purchasing patterns are reported by LaPage and Ragain *(1974)*. Clearly, plans to purchase camping-related equipment rise and fall with the camping-involvement cycle. It is not obvious, though, why purchasing intentions of other types of outdoor-recreation equipment should rise and fall along with camping involvement, unless the potential to become a camper coincides with the potential to enter other leisure-activity markets.

The third and final objective of this study was to evaluate the process by which campers exit from the camping market and to assess the importance of camper dissatisfaction with camping. A high rate of camper drop-out may represent normal attrition or may be due to growing dissatisfaction with camping experiences.

Eighty-six percent of all campers and 93 percent of the active campers expressed overall satisfaction with their last camping trips. Fewer of the inactive campers, especially the permanently inactive campers, were generally satisfied. The major sources of dissatisfaction were concerns over availability of campsites, campground cleanliness, and recreational opportunities. Less than 10 percent of any camping-involvement group expressed dissatisfaction with the size of fees, indicating that fees were not a major factor in campers' decisions to drop out of the camping market.

Campers in the permanently inactive group were older, on the average, (44 years), which suggests that some of the dropping-out may be associated with stages of the family life cycle (family-rearing period, etc.). However, a comparison of the average ages of respondents in other stages of camping involvement suggests that much of the dropping-out must be due to other reasons.

Participation in all outdoor-recreation activities generally increased from potential to active and then decreased among inactive campers. The decline was most noticeable in the permanently inactive group. Yet, more than half of the campers indicated that their primary purpose in camping was to enjoy the out-of-doors, while 16 percent said their purpose was to vacation inexpensively, and 26 percent said both. Certainly camping, if not several of its related outdoor-recreation activities, should have a life-time appeal for people with a predisposition to enjoy the out-of-doors.

In conclusion, it appears that camping images do reflect the three stages of the camping-involvement cycle. But the relationships between images and specific causes of camping inactivity such as dissatisfaction, cost, and family life-cycle, are not clearly evident. Inactivity is due to a number of causes, but perhaps most important is a lack of interest or long-term commitment. Special kinds of facilities could be designed to recapture this large and growing group; however, it seems clear that for many of them camping was simply a low-cost opportunity to try something new.

More specialized campgrounds catering to different groups, or more multiple-purpose campgrounds designed with separate sections catering to different groups, may have promise for the campground industry in the future. And information should be directed to potential campers so they may become knowledgeable about what the campground industry has to offer. Potential campers may then approach the market with more realistic expectations and aspirations, have more enjoyable camping experiences, and thereby lengthen the active stage of their camping-involvement cycle.

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APPENDIX I

Table 28.—Percentage of total participation in selected outdoor recreation activities by camping-involvement-cycle groups, 1973

Recreation activity	Campers			Potential campers				Total
	Active	Temporarily inactive	Permanently inactive	High	Medium	Low	Zero	
Picnicking	30	11	11	2	12	15	19	100
Swimming	31	13	12	2	11	14	17	100
Fishing	37	13	12	2	8	12	16	100
Motor-boating	41	13	14	2	8	10	12	100
Hunting	46	18	9	3	5	8	11	100
Hiking	52	15	11	1	9	7	5	100
Trail-bike/snowmobiling	53	14	13	2	6	4	8	100
Back-packing	74	18	3	1	4	0	(*)	100
Canoeing	42	19	10	3	7	8	11	100
Snow skiing	51	14	12	1	7	8	7	100
No participation	3	3	9	*	3	19	63	100
Per cent of total sample:	21	9	11	1	8	17	33	100

* Less than 1 per cent.

APPENDIX II

Table 29.—Percentage of expected purchases of outdoor-recreation equipment, by sample respondent groups, 1973

Expected equipment purchase	Campers			Potential campers				Total
	Active	Temporarily inactive	Permanently inactive	High	Medium	Low	Zero	
Sleeping bags	49	16	9	6	12	5	3	100
Cooler/refrigerator	41	14	9	4	10	18	4	100
Camp stove	47	20	7	5	15	5	1	100
Lantern	51	15	6	5	10	6	7	100
Shelter heater	53	9	11	6	20	(*)	(*)	99
Lightweight tent	42	35	11	8	4	—	—	100
Fishing equipment	36	16	9	3	11	13	12	100
Hunting equipment	38	18	10	4	11	11	8	100
Hiking equipment	58	8	10	6	11	7	—	100
Back-pack	64	17	8	5	6	(*)	(*)	100
Motor-boat	47	10	13	2	15	13	(*)	100
Canoe	88	12	(*)	—	—	(*)	(*)	100
Skiing equipment	59	8	7	3	7	5	11	100
Snowmobile	40	16	10	2	—	(*)	31	99
Trail bike	41	10	13	1	11	14	10	100
No purchase anticipated	12	6	12	0	6	19	45	100
Per cent of total sample	21	9	11	1	8	17	33	100

* Less than 1 per cent.

APPENDIX III

SAMPLING PROCEDURES

Sampling, interviewing, data-coding, and machine analysis for this survey were performed by the Opinion Research Corporation of Princeton, N.J., under contract with the Northeastern Forest Experiment Station, Forest Service, USDA.

The ORC master sample consists of 360 counties in the contiguous United States. This master sample of 360 counties comprises, in fact, six subsamples of 60 counties each.

To construct the sample, the counties within each state were arranged in order of descending population size; and all the states were grouped in geographical order from Maine to California. Sixty counties were then chosen by statistical procedures that insure representative geographical distribution. This process was repeated to obtain the six subsamples that make up the master sample of 360 counties.

The next step in the sampling design was to select an area from each of the 360 counties in the master sample. Again, a probability sampling method was used to select, within each county, a minor civil division (MCD) as defined by the Bureau of the Census. A minor civil division may be a town, township, city, or part of a city. The probability that any particular minor civil division was selected in a county was proportional to the population of that minor civil division. Thus the larger a minor civil division, the greater the likelihood that it be selected. The minor civil division, then, is the primary sampling unit.

Once the MCD has been selected, the next step is to determine those households where interviewing is to take place. Under the ORC National Probability Sample procedure, any current listing of household locations, even if incomplete, constitutes the first stage of the sampling plan. From this list of households, one or more addresses are chosen at random. Each of these addresses defines the place that the interviewer begins following the interviewing site-selection process. The interviews in a cluster or neighborhood do not begin at the household selected from the list, but at the adjacent household, which may or may not be on the original list. Thus the list does not define the universe of households in an MCD, but rather the list of households adjacent to possible starting points. Depending on the number of households contacted from each starting point, the number of starting points chosen, and the criteria for being included on the original list, every household in the MCD has a known, or knowable, probability of being included in the ORC sample.

The specific persons to be interviewed are selected as follows:

1. A certain number of starting points are selected from the telephone books covering the minor civil divisions or communities selected. The starting points are chosen in a manner that, within the minor civil division, each household listed in the phone book has an equal chance of being selected.
2. Each starting point selected determines a group of households, called a cluster, in which interviews are conducted. This cluster of households includes households both with and without listed telephones. The first household in which an interview is conducted is the household immediately to the left of the household selected from the telephone book as the starting point. Thus, the first household can be one either with or without a telephone.
3. The interviewer conducts an interview in the first household and then works through the group of households following a prescribed rule. The interviewer continues working through the cluster until interviews have been completed in a preassigned number of households.
4. A respondent-selection procedure determines for the interviewer which person to interview in any given household. Every eligible respondent in the household has the same chance to be interviewed as any other eligible respondent. The interviewer is not allowed to make any substitutions.

Once all interviews have been completed, weighting procedures are employed to ensure that the sample properly represents the population from which it was drawn.

This sampling procedure is rigorous in concept and practice and allows for the exact determination of the statistical precision of any finding.

APPENDIX IV

STATISTICAL INTERPRETATION

Reliability of Survey Percentages

Results of any sample are subject to sampling variation. The magnitude of the variation is measurable and is affected by the number of interviews and the level of the percentages expressing the results.

The table below shows the possible sample variation that applies to percentage results reported from the Opinion Research Corporation sample. The chances are 95 in 100 that a Caravan survey result does not vary, plus or minus, by more than the indicated number of percentage points from the result that would be obtained if interviews had been conducted with all persons in the universe represented by the sample.

Size of sample on which caravan survey result is based (No. of interviews)	*Approximate sampling tolerances applicable to percentages at or near these levels*		
	10% or 90%	*30% or 70%*	*50%*
2,000	2%	3%	3%
1,000	2%	4%	4%
500	3%	5%	5%
250	5%	7%	8%
100	7%	11%	12%

Sampling Tolerances When Comparing Two Samples

Tolerances are also involved in the comparison of results from different parts of any one Opinion Research Corporation sample and in the comparison of results between two different ORC samples. A difference, in other words, must be of at least a certain size to be considered statistically significant. The table below is a guide to the sampling tolerances applicable to such comparisons.

Size of samples compared	*Differences required for significance at or near these percentage levels**		
	10% or 90%	*30% or 70%*	*50%*
2,000 and 2,000	2%	4%	4%
2,000 and 1,000	3%	4%	5%
1,000 and 1,000	3%	5%	6%
1,000 and 500	4%	6%	7%
500 and 500	5%	7%	8%
500 and 200	6%	9%	10%
200 and 200	7%	11%	12%
200 and 100	9%	14%	15%
100 and 100	10%	16%	17%

---

* Based on 95 chances in 100.

APPENDIX V

INTERVIEWING MATERIALS

SECTION C

The following set of questions concerns your interest in family camping and your experiences with any of the types of equipment shown on this card --

SHOW EXHIBIT C-1

C1. Within the past two years, have you visited a camping show or recreational vehicle show where any of these types of equipment were displayed?

1 YES
2 NO
3 DON'T KNOW

C2. Do any of your friends own or use any of the types on this card?

1 YES
2 NO
3 DON'T KNOW

C3. Considering the total cost of camping, including taxes on equipment, campsite fees, extra tolls and insurance, and equipment costs, do you feel that camping is more economical or less economical or about the same as other ways of traveling and taking a vacation?

1 MORE ECONOMICAL
2 LESS ECONOMICAL
3 ABOUT THE SAME
4 DON'T KNOW

C4. As briefly as possible, could you tell me what thoughts come to mind as you think about living at a campground for a few days in any of these types of equipment.

SHOW EXHIBIT C-5

C5. This exhibit contains descriptive words that can be used to describe camping. As I read the letter before the descriptive word, please choose a point on the scale which is closest to how it would describe your impression of camping.

For instance, if you will look above the list of words, there is an example. If you were describing the weather and you felt it was "a cold day," you would place it on the scale toward #5.

The colder it was, the closer to #5 you would place it. On the other hand, if you felt it was a hot day, you would place it on the scale toward #1. The hotter you thought it was, the closer you would place it to #1. If you felt it was neither very cold nor very hot, you would place it toward the middle of the line.

First, let's start with Description A. What point on the scale is closest to how Description A best describes camping to you. (INTERVIEWER: CIRCLE # FOR DESCRIPTION A AND REPEAT FOR EACH DESCRIPTION.)

						No Answer
A	1	2	3	4	5	0
B	1	2	3	4	5	0
C	1	2	3	4	5	0
D	1	2	3	4	5	0
E	1	2	3	4	5	0
F	1	2	3	4	5	0
G	1	2	3	4	5	0
H	1	2	3	4	5	0
I	1	2	3	4	5	0
J	1	2	3	4	5	0
K	1	2	3	4	5	0
L	1	2	3	4	5	0
M	1	2	3	4	5	0

TURN BACK TO EXHIBIT C-1

C6. Have you ever gone on an overnight trip with your family, or with friends, and used any of the types of equipment shown on this card? Do not include any camping trips you may have taken with scouting groups or military experience.

1 YES → SKIP TO Q. C17
2 NO
3 DON'T KNOW

(IF "NO" OR "DON'T KNOW" ON Q. C6, ASK):

C7. Have you, as a household, considered such a camping trip in the past 1-3 years?

1 YES
2 NO
3 DON'T KNOW → SKIP TO Q. C14

(IF "YES" ON Q. C7, SHOW EXHIBIT C-8, AND ASK):

C8. Did you decide not to camp at that time for any of these reasons? Just read me the numbers that apply please. (Check as many as apply.)

1 2 3 4 5 6 OTHER (Specify)________________
7 NONE OF THESE
8 NO OPINION

C9. When you last considered going on a camping trip, had you selected a region or part of the country you wanted to visit?

1 YES
2 NO
3 DON'T KNOW

(IF "YES" ON Q. C9, ASK):

C10a. Did you write for information or try in other ways to determine the availability of campgrounds?

1 YES
2 NO
3 DON'T KNOW

C10b. Did you attempt to reserve a campsite in advance?

1 YES
2 NO
3 DON'T KNOW

C11. Did you check into the cost of buying camping equipment?

1 YES
2 NO
3 DON'T KNOW

C12. Did you look into the cost of renting your equipment?

1 YES
2 NO
3 DON'T KNOW

C13. Did you look into the possibilities of borrowing the equipment?

1 YES
2 NO
3 DON'T KNOW

SHOW EXHIBIT C-14

C14. Which of the statements on this card best describes your household's present attitude toward camping. Just read me the number, please.

1 NEXT YEAR
2 HOPE TO GO IN FUTURE
3 UNLIKELY TO GO
4 NOT INTERESTED → SKIP TO Q. C29
5 DON'T KNOW

SHOW EXHIBIT C-1 AGAIN

C15. Which of these types of equipment will you probably use on your first trip? Just read me the number please. (INTERVIEWER: CIRCLE APPROPRIATE LETTERS BELOW AND ASK Q. C16 FOR EACH TYPE USED IN Q. C15.)

1. TENT	C16a. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
2. CAMPING TRAILER (Folding)	C16b. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
3. TRAVEL TRAILER (any kind, any size)	C16c. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
4. TRUCK CAMPER	C16d. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
5. PICK-UP COVER	C16e. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
6. MOTOR HOME	C16f. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
7. VAN OR BUS CONVERSION	C16g. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
X. OTHER (Please specify): ______________________	C16h. For this trip will you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
Y. DON'T KNOW	

(INTERVIEWER: CHECK BACK TO Q. C6, IF "YES" ON Q. C6, ASK Q. C17; OTHERWISE, SKIP TO Q. C29.)

C17. In what year did you last go camping? (Check one)

1 1973 → SKIP TO Q. C20
2 1972
3 1971
4 1970, OR EARLIER

(IF "1972 OR EARLIER" ON Q. C17, ASK):

C18. Can you recall why you stopped camping? (PROBE: What specifically has kept you from going camping again since that last trip?)

☐

X HAVE NOT STOPPED -- SKIP TO Q. C20

C19. Have you sold your tent, trailer or other camping shelter, have you given it away, or do you still have it?

1 SOLD IT (or is selling it)
2 GIVEN AWAY
3 STILL HAVE IT
4 DID NOT OWN (rented or borrowed)
5 DON'T KNOW

C20. In what year did you first go camping as an adult?

1 1973 → SKIP TO Q. C22
2 1972
3 1971
4 1970
5 BEFORE 1970
6 DON'T RECALL

(IF "1972 OR EARLIER" ON Q. C20, ASK):

C21. Do you camp about the same number of nights each year, or has your participation in camping been increasing or decreasing in the past few years? (Check one)

1 ABOUT THE SAME EACH YEAR
2 INCREASED LATELY
3 DECREASED LATELY
4 DON'T KNOW

C22. During the past year, did the gasoline shortage -- or the threat of a gas shortage -- cause you to cancel any of your camping trips, to cut them shorter than you planned, or to postpone the purchase of a major item of camping equipment? (Check as many as apply)

1 TRIP CANCELLATIONS
2 SHORTENED TRIPS
3 POSTPONE PURCHASES
4 NONE OF THE ABOVE

TURN BACK TO EXHIBIT C-1

C23. On your last camping trip, which of these types of camping equipment did you use. Just read me the letter please.

1. TENT	C24a. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
2. CAMPING TRAILER (Folding)	C24b. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
3. TRAVEL TRAILER (Any kind, any size)	C24c. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
4. TRUCK CAMPER	C24d. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
5. PICK-UP COVER	C24e. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
6. MOTOR HOME	C24f. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
7. VAN OR BUS CONVERSION	C24g. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
X. OTHER (Please specify): ____________________	C24h. For this trip did you 1. Rent 2. Borrow 3. Purchase 4. Or already own this equipment? 5. DON'T KNOW
Y. DON'T KNOW	

C25. On your last camping trip were you generally satisfied or generally dissatisfied with: (INTERVIEWER: READ EACH STATEMENT BELOW AND CIRCLE RESPONDENT'S ANSWER.)

	GENERALLY SATISFIED	GENERALLY DISSATISFIED	DON'T KNOW	DOES NOT APPLY TO MY STYLE OF CAMPING
A. The availability of tentsites and trailersites	1	2	3	4
B. The availability of recreational facilities at the campground	1	2	3	4
C. The cleanliness and condition of campgrounds	1	2	3	4
D. The availability of hook-ups	1	2	3	4
E. The level of camping fees	1	2	3	4
F. The trip as a whole	1	2	3	4

C26. On that trip did you camp at private campgrounds, public campgrounds such as state parks, or both public and private?

1 PRIVATE
2 PUBLIC
3 BOTH
4 DON'T KNOW

C27. Thinking back to the time of your last camping trip, can you recall whether that trip was the result of long planning over a period of several days or weeks, or was it more like a "spur of the moment" idea with less than 2 days of planning?

1 CAREFUL PLANNING
2 IMPULSE
3 DON'T KNOW

C28. Would you describe your camping as primarily a way of vacationing inexpensively, or as basically your way of enjoying the out-of-doors, hiking, swimming, fishing, and other physical activities?

1 WAY OF VACATIONING INEXPENSIVELY
2 A WAY OF ENJOYING OUT-OF-DOORS
3 BOTH
4 NO OPINION

INTERVIEWER: ALL RESPONDENTS ARE ASKED THE FOLLOWING:

SHOW EXHIBIT C-29

C29. During the next year, which of the following types of equipment do you expect to purchase? (Just read me the numbers, please.) (Circle each item answered.)

1 2 3 4 5 6 7 8 9 10

11 12 13 14 15 16 OTHER (Please specify):____________________

17 NONE OF THESE

SHOW EXHIBIT C-30

C30. Many campgrounds are provided on public lands such as State and National Parks. Here are two opposite ideas about fees for camping at these public parks. Which of these statements do you most agree with?

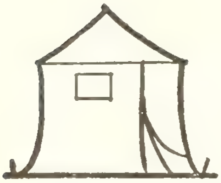
1 FEES COVER ALL COSTS
2 FEES KEPT LOW
3 NO OPINION

SHOW EXHIBIT C-31

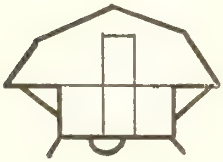
C31. During the past 12 months have you, personally, participated in any of the following types of leisure time activties? (Just read me the numbers, please.)

1 BOATING (motor boats)
2 CANOEING
3 FISHING
4 HIKING
5 SKIING (on snow)
6 PICNICKING (away from home)
7 SWIMMING (away from home)
8 TRAIL BIKE RIDING OR SNOWMOBILING
9 HUNTING (any type, any place)
10 BACK PACKING

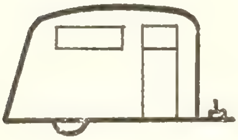
EXHIBIT C-1



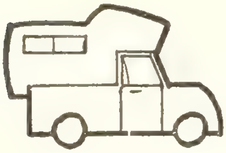
1 TENT (Any kind, any size)



2 CAMPING TRAILER (Folding)

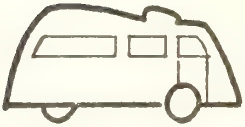


3 TRAVEL TRAILER (Any kind, any size)

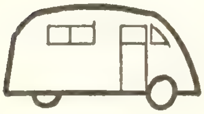


4 TRUCK CAMPER

5 PICK-UP COVER



6 MOTOR HOME



7 VAN OR BUS CONVERSION

Example:

A warm day	1	2	3	4	5	A cold day

EXHIBIT C-5

I think camping would be:

A....... Interesting	1	2	3	4	5	Boring
B..Unfriendly people	1	2	3	4	5	Friendly people
C............. Clean	1	2	3	4	5	Dirty
D......... Dangerous	1	2	3	4	5	Safe
E........ Refreshing	1	2	3	4	5	Tiring
F........... Crowded	1	2	3	4	5	Uncrowded
G......... Expensive	1	2	3	4	5	Not expensive
H......... Difficult	1	2	3	4	5	Easy
I.......... Pleasant	1	2	3	4	5	Unpleasant
J.............. Work	1	2	3	4	5	Fun
K.........Convenient	1	2	3	4	5	Not convenient
L........Complicated	1	2	3	4	5	Easy
M..... Uncomfortable	1	2	3	4	5	Comfortable

EXHIBIT C-8

Reasons for deciding not to camp

1 The expected costs of camping.

2 We lacked information about camping equipment.

3 We lacked information about places to camp.

4 We were uncertain about whether we would enjoy associating with campers.

5 The "gas shortage."

6 Other reasons (Please specify)

EXHIBIT C-14

1. We expect to go camping next year.

2. We hope to go camping at some time in the future, but probably not next year.

3. We are unlikely to go camping in the foreseeable future.

4. We are definitely not interested in camping.

EXHIBIT C-29

Next year I expect to buy:

1. FISHING EQUIPMENT
2. SNOWMOBILE
3. CANOE
4. SKIING EQUIPMENT
5. MOTOR BOAT
6. HUNTING EQUIPMENT
7. TRAIL BIKE - OR OFF-ROAD RECREATIONAL VEHICLE
8. HIKING EQUIPMENT
9. BACK PACK
10 SLEEPING BAGS
11. CAMP STOVE
12. TRAILER OR TENT HEATER
13. LIGHT WEIGHT, MOUNTAINEERING TENT
14. COOLER CHEST, OR REFRIGERATOR
15. GAS OR PROPANE LANTERN
16. OTHER (Please specify)

EXHIBIT C-30

1 Camping fees should be set high enough to cover all - or most - of the costs of operating a public campground.

2 Camping fees on public lands should be kept low and most of the costs of operating campgrounds should be paid out of our taxes.

EXHIBIT C-31

1 Boating (motor boats)

2 Canoeing

3 Fishing

4 Hiking

5 Skiing (on snow)

6 Picnicking (away from home)

7 Swimming (away from home and outdoors)

8 Trail Bike Riding or Snowmobiling

9 Hunting (any type, any place)

10 Back Packing

APPENDIX VI

Table 30.—Image indexes for selected demographic and camping market groups

Item	n	image-index
TOTAL U.S. PUBLIC	2207	1.689
Sex:		
Men	1067	1.991
Women	1116	1.443
Age (years):		
18–29	590	2.560
30–39	418	1.609
40–49	327	1.517
50–59	331	1.462
60+	529	1.252
Education:		
Less than high school	758	1.733
High school	757	1.772
Some college	676	1.573
Occupation:		
Professional	283	1.890
Managerial	295	1.455
Clerical, sales	212	1.522
Craftsman, foreman	462	1.818
Other manual, service	410	2.018
Farmer, farm laborer	66	1.179
Place of residence:		
Rural	310	1.676
Urban (non-metro)	307	1.977
50,000–999,999	651	1.766
1,000,000 or more	939	1.567
Region:		
Northeast	516	1.346
North Central	620	1.623
South	724	1.801
West	347	2.230
Income:		
Under $5,000	383	2.033
$5,000–$6,999	273	1.885
$7,000–$9,999	413	1.868
$10,000–$14,999	560	1.631
$15,000 or more	548	1.406
Race:		
White	1979	1.673
Nonwhite	188	1.970
Family size:		
No children	1102	1.608
Children under 18	1105	1.766
Home ownership:		
Own home	1514	1.531
Rent home	664	2.130
Market class:		
Active campers	450	4.274
Temporarily inactive	213	2.937
Permanently inactive	295	1.847
High and medium potential	181	2.616
Low and zero potential	1053	0.842

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Kottke, Marvin W., Malcolm I. Bevins, Gerald L. Cole, Kenneth J. Hock, and Wilbur F. LaPage.

1975. **Analysis of the campground market in the Northeast. Report III. A perspective on the camping-involvement cycle.** NE. For. Exp. Stn., Upper Darby, Pa.
35 p. (USDA For. Serv. Res. Pap. NE-322)

A report on a study of the national camping market, conducted in 1973, updating findings of a similar survey conducted in 1971. Based on a nationally representative sample of 2,213 households, the total camping market is estimated to include 14.3 million households of active campers, 6.1 million who are temporarily inactive, and 6.1 million who are potential additions to the market. A detailed analysis of the popular image of camping as held by each of the major segments of the market is included, and the reasons for permanent and temporary dropping out of the camping market are examined.

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PALLET REPAIR AND SALVAGE

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by Richard E. Frost and Hollis R. Large

USDA FOREST SERVICE RESEARCH PAPER NE-323
1975
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

THE AUTHORS

RICHARD E. FROST received a bachelor of science degree in wood technology from the University of Massachusetts in 1967. During the summer of 1966 he was a management trainee with U.S. Plywood Corporation. He joined the Forest Products Marketing Laboratory, USDA Forest Service in June 1967. He has been employed as a research scientist and research technologist collecting and evaluating data on unitization of industrial and commercial commodities on wooden pallets.

HOLLIS R. LARGE received his bachelor of science degree in forestry from the University of Tennessee in 1969 and his master's degree from the same institution in 1971. He joined the staff of the USDA Forest Service, Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, West Virginia, in 1971. At the time of this study he was a forest products technologist.

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PALLET REPAIR AND SALVAGE

ABSTRACT

Efficient unit-load handling with permanent pallets requires a well-organized pallet repair program. To provide basic information on pallet damage that could be used in establishing repair standards, we inspected a total of 1700 damaged pallets at four repair facilities. All damage was recorded by type, severity, and location. This survey determined that missing deckboards at the ends of the pallet account for more than 50 percent of the total deck damage and longitudinal breaks and splits outside the stringer notches account for more than 80 percent of the total stringer damage. This information should benefit those who use and repair wooden pallets.

INTRODUCTION

One aspect of the pallet industry that receives relatively little attention is the market for used pallets. Of the wood used for pallets, skids, bases, crates, containers, and dunnage for shipping products in the United States, approximately 10 board feet is consumed for each pallet-load-equivalent shipped. Only about one-fifth of the total product transported on pallets is shipped on permanent structures, and millions of board feet of reusable wood is discarded annually. The waste is greatest in industries with high-value products, where the cost of wood shipping materials is an insignificant addition to the total cost of the product.

But the absolute cost is of major concern to the final consumer, who ultimately must pay for the wasteful use of raw materials. Wood packing and shipping materials cost the economy of the United States approximately $1.75 for each pallet-load-equivalent of product shipped, instead of approximately $0.60 as they would if high-quality permanent pallets were used. This amounts to an avoidable expense of approximately $690 million annually for the 600,000,000 pallet-load-equivalents shipped.

Although the most efficient use of materials is in high-quality reusable structures, nearly 80 percent of the wood now used in packing and shipping is not reusable in its original form. To reuse the discarded materials, it is necessary to disassemble the structures, salvage usable materials, and reassemble them, often into different products. At a time when wood raw material is scarce and in demand, there is increased interest in the potential of salvage. This interest is further stimulated by public concern over the disposal of waste products and its effects on the environment.

Unfortunately, although the restricted supply of wood has resulted in increased prices, the reaction of industry is an attempt to maintain the present costs by purchasing lower quality shipping materials. This aggravates the supply situation because even less material can be reused, and costs and prices begin to spiral upward. The net result is that already scarce materials are used less efficiently and become more scarce.

A more rational course would be to maintain the present costs in the long run by purchasing and using reusable shipping materials, which have a higher initial cost but a lower cost per use because they last longer and need less maintenance and repair. In the competitive marketplace, such a course of action would require concerted action by all the firms in an industry. Individual firms that want to follow such a policy must make a concerted effort to induce other firms with which they do business to follow the same policy. This rarely happens, and one result is that the salvage and repair industry booms.

BACKGROUND

Pallet users do a limited amount of repair work to protect their investment in pallets. Pallet manufacturers repair pallets on a limited scale as a service to special customers, but the pallet manufacturer views a damaged pallet as a potential replacement order. The pallet user views a damaged pallet as a piece of packaging material that is not compatible with his paper compactor and a liability because of its high disposal cost. This attitude is especially prevalent among nonmanufacturing firms that receive pallets under materials but do not use them to ship their products.

The underlying problem is that the pallet manufacturer has little knowledge of how a pallet is used in a materials-handling and distribution system, while the pallet user has little knowledge of the principles and mechanics of pallet manufacturing. Both the pallet manufacturer and the pallet user need education about the value of a pallet in a total materials-handling and physical distribution system.

In recent years commercial pallet repair companies have emerged. Several of these companies are well-established going concerns. When they perform low-quality repairs, it is because they have no vested interest in the utility of the repaired pallets. Still, the repair companies are providing an essential service and an accepted product in an ever-expanding market.

THE STUDY

Purpose

The purpose of this study was to: (1) measure the frequency and kind of damage sustained by pallets and (2) compare the repair criteria used by different companies. This information should provide a basis for:

(1) development of objective pallet-repair standards,
(2) reasonably accurate estimation of repair costs, and
(3) more efficient application of pallet-repair technology.

Methods

Pallets were inspected at four locations. Two were well-established commercial pallet repair and salvage (R & S) companies, one in Massachusetts and one in New Jersey; two were "in-house" pallet repair facilities in large food distribution centers (DC) in Maryland.

Approximately 800 48- by 40-inch 4-way-entry reusable hardwood food-industry pallets were inspected at the R & S companies, and another 900 were inspected at the DC repair facilities. The location, type, and severity of damage was recorded for each damaged part of each pallet. The damage locations tallied were:

TDEB	top deck endboard
BDEB	bottom deck endboard
BDNB	bottom deck notchboard (chamfered boards in the center cluster of the bottom deck)
BDCB	bottom deck centerboard (nonchamfered boards in the center of the bottom deck)
TDCB	top deck centerboard
ES	edge stringer
CS	center stringer

The types of damage tallied were:

MISS	part missing
CB	cross break
DB	diagonal break
LB	longitudinal break
LS	longitudinal split
JT	joint failure

Using a scale developed for previous studies, we rated the severity of damage from one to nine. There were three classes of damage: minor damage that did not influence the structural strength of the pallet; moderate damage that caused a weakening of the structure but did not require repair; and severe damage that caused major weakening of the structure and inactivated the pallet until it could be repaired. Only severe pallet damage (rated seven to nine) was recorded in this study.

The damage severity codes in the "severe" class are:

Damage rating	*Pallet part*	*Extent of damage*
7	Deckboards	A cross break or a longitudinal break with the parts in place and not more than one joint damaged. A diagonal break with not more than one-eighth of the part missing and not more than one joint damaged.
	Stringers	Any break with the parts in place and not more than one joint damaged.
8	Deckboards	Any break or combination of damages which causes two joints of one part to be ineffective. Any break with more than one-eighth but less than one-half of the part missing.
	Stringers	Any break with not more than one-half of the cross-section area of the part missing. Any break which causes two joints in any one part to be ineffective.
9	Deckboards	Any break or combination of damages which causes three joints in one part to be ineffective. Any break with more than one-half of the part missing.
	Stringers	Any break with one-half or more of the cross-section area of the part missing. Any break which causes three joints in one part to be ineffective.

RESULTS

Damage

The average severity of damage rating per damaged part was essentially the same at all four repair locations: 8.3 at R & S #1, R & S #2, and DC #1; and 8.6 at DC #2.

Although the parts at all repair locations were damaged with the same severity, they were not damaged with the same frequency (table 1). The pallets processed at the R & S companies needed repair of 16 percent of their parts; those processed at the DC facilities needed repair of only 6 percent of their parts.

The pallets processed at the R & S companies had 13 percent of their deckboards damaged, and those at the DC facilities had 7 percent damaged. At the R & S companies 30 percent of the stringers were damaged; at the DC facilities 5 percent were damaged.

Missing parts accounted for about 55 percent of the damaged deckboards, while lengthwise splits and breaks accounted for about 85 percent of the damaged stringers.

At the R & S companies, 76 percent of the damaged stringers had complete breaks (CB, DB, LB), while at the DC facilities only 50 percent had complete breaks. Lengthwise splits and breaks accounted for 91 and 81 percent, respectively, of the damage to stringers.

Table 1 shows the frequencies of different types of deckboard damage, as percentages of the total deckboard damage. For example, 47

Table 1.—Types of damage to deckboards, in percentage of all deckboard damage

Part location	Type of damage						Percent of all deckboard damage
	MISS	CB	DB	LB	LS	JT	
			DC FACILITIES				
TDEB	47	16	18	12	1	6	26
TDCB	34	34	3	0	0	28	7
BDEB	64	9	9	7	1	10	28
BDNB	86	3	3	3	0	5	30
BDCB	77	13	0	5	0	5	9
Deckboard average	53	21	6	4	0	16	100
			R & S COMPANIES				
TDEB	42	9	27	8	1	12	26
TDCB	45	25	10	0	1	18	11
BDEB	60	10	15	6	1	8	30
BDNB	79	12	3	2	1	3	26
BDCB	86	8	4	0	0	2	7
Deckboard average	57	16	11	2	1	11	100

percent of the TDEB damages tallied at the DC facilities were missing parts, 16 percent were cross breaks, and 6 percent were joint failures. The last column shows that damaged TDEBs accounted for 26 percent of all the deckboard damage tallied. The bottom row shows that 23 percent of the total deckboard damages were missing parts, 21 percent were cross breaks, and 16 percent were joint failures.

The frequencies of different types of damage to stringers are shown in table 2.

Table 2.—Types of damage to stringers, in percentage of all stringer damage

Part location	Type of damage				Percent of all stringer damage
	CB	DB	LB	LS	
		DC FACILITIES			
ES	4	1	34	60	81
CS	6	6	56	31	19
Stringer average	5	3	41	50	100
		R & S COMPANIES			
ES	10	10	57	23	73
CS	9	6	58	27	27
Stringer average	10	9	57	24	100

The proportion of damage in the different parts of the pallet was similar at all facilities, although the incidence of damage was considerably greater at the R & S companies (table 3).

For example, 13 percent of the TDEBs were damaged in the pallets processed through the DC facilities, and they represented 22 percent of the total pallet damage. The pallets processed through the R & S companies had 25 percent of the TDEBs damaged, and they accounted for 17 percent of the total pallet damage.

The different areas of the stringers were found to be damaged in about the same proportion at all facilities; the end areas were damaged the most and the notch areas were damaged the least:

	Percent of damage			
	End areas	*Center areas*	*Notch areas*	*Total*
DC	63	33	4	100
R & S	62	30	8	100

Each stringer has two notch areas, two end areas, and only one center area. The actual frequency of damage to each of the ends was nearly the same as to the center. However, the frequency of damage in the notch areas

Table 3.—Percentage of parts damaged and repaired at two types of repair facilities

	DC				R & S			
Part location	No. parts per pallet	Percentage of parts damaged	Percentage of damaged parts repaired	Percentage of total damage per pallet	No. parts per pallet	Percentage of parts damaged	Percentage of damaged parts repaired	Percentage of total damage per pallet
TDEB	2	13	94	22	2	25	97	17
BDEB	2	15	97	26	2	29	92	20
EB average	4	14	95	48	4	27	95	37
BDNB	2	15	19	26	2	25	96	17
BDCB	2	5	76	9	2	8	99	5
TDCB	6	1	86	2	6	3	94	2
CB average	10	2	83	37	10	4	96	24
Deckboard average	14	7	77	85	14	13	95	61
ES	2	6	48	10	2	32	100	22
CS	1	3	37	5	1	24	100	16
Stringer average	3	5	45	15	3	30	100	38
Average—all parts	17	6	72	100	17	16	96	100

was considerably less; notch area damage accounted for less than 20 percent of the total stringer damage at the R & S companies, and less than 10 percent at the DC facilities.

REPAIR PRACTICES

Commercial Pallet Repair and Salvage Companies

The repair criteria used by the two R & S companies were similar: if a pallet could be repaired, they repaired all damaged parts of it; if a pallet could not be repaired, the usable parts were salvaged. The repair criteria used by the DC facilities were different: one DC facility repaired about 85 percent of the damage and the other repaired less than 60 percent. The policy of the latter DC facility was to do the minimal repair needed to allow the pallet to be used for one more trip.

The commercial pallet repair and salvage companies acquire pallets by three primary means: they get discards from the food distribution center repair facilities; they have contracts with pallet-using firms to repair damaged pallets for a fee, and retain some of the damaged pallets which cannot be repaired for the specified fee; and they acquire pallets and skids free or at minimal cost from pallet users with excess pallet inventories.

One of the commercial repair and salvage companies (R & S #1) dismantles pallets with hydraulic pallet-dismantling machines, which hold one deck of the pallet stationary and force the stringers away from that deck. Nails protruding from the disassembled parts are cut off with a right-angle grinder. This company salvages enough lumber to repair the damaged pallets and manufacture new pallets. About 1,500 pallets are repaired per day, and the company serves an area roughly 200 miles in diameter.

R & S #1 sorts all pallets and skids by size and condition into piles to be dismantled, repaired, or returned to service as is. Two-man crews, each with its own work table, pneumatic nail guns, hand tools, and repair parts, operate at a work station served by forklift trucks that supply damaged pallets and remove repaired ones. Each two-man crew repairs an average of 30 to 40 pallets per hour—15 to 20 per man-hour.

The other commercial repair and salvage company (R & S #2) dismantles pallets manually with crowbars and hammers. This company also purchases new lumber to supplement the salvaged lumber. All the new and used lumber goes into the repair of pallets; no new pallets are manufactured. About 500 pallets are repaired per day, and the company serves an area roughly 75 miles in diameter.

R & S #2 does no sorting and the repair personnel work individually, not in crews. There are no definite work stations, and each man is responsible for sorting the repaired pallets by size as well as for manually disassembling the pallets that are damaged beyond repair. Each man averages 10 to 12 pallets repaired or dismantled per hour.

Both companies used chamfered and square-edge 4-inch and 6-inch lumber for deckboard repairs. Six-inch and 18-inch long 2- by 4-inch blocks are used for stringer repairs. Both facilities use pneumatically-driven helically-threaded nails. Neither company sets a limit on the number of repairs per pallet, but R & S #2 sells reusable pallets with six or more repairs as expendables.

Both companies leave trailers at the pallet users', and the users load the damaged and discarded pallets and skids on the trailer as they are discarded. When the trailer is loaded the repair company picks it up and replaces it with an empty one.

The mix of pallets handled by the commercial repair and salvage companies averaged:

62 percent 48- by 40-inch 4-way entry
    reusable food industry pallets
25 percent reusable pallets of other types
9 percent expendable pallets
4 percent skids

At the R & S companies 5 percent of the food pallets processed were not damaged; the other 95 percent had an average of 3.5 damages per pallet. At R & S #1, 91 percent of the pallets were damaged; they had an average of 3.3 damages per pallet. At R & S #2, 100 percent were damaged, with an average of 4.3 damages each. Eight percent of the total food pallets processed were damaged too severely to be repaired and were disassembled for salvage. The R & S companies repaired 95 percent of the damaged deckboards and 100 percent of the damaged stringers in the pallets they returned to service.

Food Distribution Center Repair Facilities

The food distribution center (DC) in-house pallet repair facilities are part of the distribution centers' salvage operations. The distribution centers collect from the retail stores and dispose of such items as milk cases, fiber containers, and pallets.

At the DC facilities a smaller proportion of the food pallets were damaged than at the R & S companies, and they had fewer damages per pallet. Sixty-nine percent of the food pallets (73 percent at DC #1 and 65 percent at DC #2) were damaged, with an average of 2.2 damages per pallet. Ten percent of the food pallets processed through the DC facilities were discarded and sent to the R & S companies.

Each DC repair facility employed a two-man repair crew, whose full-time job was pallet inspection and repair. Each crew was provided with a work table, pneumatic nail guns, hand tools, and powered forklift equipment. The repair crews inspect and sort all the pallets returned from the retail stores as well as the pallets damaged at the distribution centers. Many of the pallets do not need repairs, and this is reflected in a greater number of pallets handled per hour than at the R & S companies. The repair facilities usually discard pallets if two or more stringers are damaged severely. Neither limits the number of deckboards repaired per pallet.

One DC facility (DC #1) uses new chamfered and square-edge 4- and 6-inch lumber for deckboard repairs and 48-inch notched stringers for reinforcing damaged stringers. This facility uses pneumatically-driven helically-threaded nails. The two-man repair crew handles an average of 40 to 50 pallets per hour (10 to 25 per man-hour).

The other DC facility (DC #2) uses only new square-edge 4-inch lumber for deckboard repairs, and does not repair damaged stringers. This facility uses pneumatically-driven smooth shank "T" nails. The two-man repair crew handles 50 to 60 pallets per hour (25 to 30 per man-hour).

The mix of pallets handled by the DC repair facilities averaged:

72 percent food industry pallets
15 percent dairy pallets (36- by 36-inch 2-way entry)
10 percent reusable pallets other than food and dairy pallets
4 percent expendable pallets and skids

The pallets returned to service at DC #1 had 100 percent of the damaged end and center deckboards and 90 percent of the damaged stringers repaired; however, only 5 percent of the damaged bottom deck notchboards were repaired. The pallets returned to service at DC #2 had only 69 percent of the damaged deckboards and none of the damaged stringers repaired.

Compared to the DC companies, the R & S companies started with more extensively damaged pallets and repaired a greater percentage of the damaged parts before the pallets were returned to service. Pallets discarded by the DC facilities averaged 3.3 damages each; those received by R & S companies averaged 3.6 damages each. The DC facilities repaired 72 percent of the damaged parts and the R & S companies repaired 96 percent before the pallets were returned to service. The R & S companies do a more complete job of repair because the pallets must be restored to salable condition.

DISCUSSION

Instead of an expense and a nuisance, damaged pallets can be an asset if they can be repaired and salvaged. With the pallet dismantling machines, R & S #1 was able to salvage 83 percent of the undamaged notched stringers, 97 percent of the undamaged solid stringers, and 95 percent of the undamaged deckboards.

Although virtually all the food pallets handled by the R & S companies were damaged more severely than those repaired by the DC facilities, 92 percent of them were repaired by the R & S companies and resold. An average of 16 pallets per trailer load were damaged too severely for the R & S companies to repair. When these pallets were disassembled with the hydraulic dismantler they produced an average of 8.5 board feet of undamaged deckboard material and 2.2 board feet of undamaged stringer material each.

There were 182 48- by 40-inch 4-way-entry pallets that could be repaired in the average trailer load of pallets received at R & S #1; they averaged 332 damaged deckboards and 164 damaged stringers. The repair of these damaged pallets required approximately 40 board feet of deckboard material and 80 linear feet (55 board feet) of stringer material.

There is a limited demand for the 80 reusable pallets of other types in the average trailer load. If two-thirds of these were dismantled they would yield as much lumber per pallet as the severely damaged food pallets. This would provide an additional 450 board feet of deckboard lumber and 75 board feet of stringer lumber. This material plus the lumber salvaged from the disassembled food pallets would be enough to repair the damaged food pallets and the remaining third of the reusable pallets of other types.

One company has recently produced a pallet dismantling machine which uses cutter discs to cut the nails. The pallet is hydraulically forced against two stationary cutter discs which cleanly sever the nails at the deckboard-stringer joints. Pallets can be disassembled by this machine about as rapidly as by the R & S #1 dismantling machine. However, the machine is not yet in commercial production.

The price of a used food pallet, delivered to the user, is about 65 percent of the delivered price of a new food pallet. The experience of the commercial pallet repair and salvage companies is that most pallet users are not averse to purchasing repaired pallets. Indeed, when the price differential between new and repaired pallets is 35 percent, the preference is usually for the repaired pallets.

Frost, Richard E., and Hollis R. Large.
1975. **Pallet repair and salvage.** NE. Forest Exp. Stn., Upper Darby, Pa.
7. p. (USDA Forest Serv. Res. Pap. NE-323)

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Forest Management and Nutrient Cycling in Eastern Hardwoods

James H. Patric and
David W. Smith

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MANUSCRIPT RECEIVED FOR PUBLICATION 3 DECEMBER 1974

Forest Management and Nutrient Cycling in Eastern Hardwoods

Abstract

The literature was reviewed for reports on nutrient cycling in the eastern deciduous forest, particularly with respect to nitrogen, and for effects of forest management on the nutrient cycle. Although most such research has dealt with conifers, a considerable body of literature relates to hardwoods. Usually, only those references that dealt quantitatively with nutrient cycling were cited.

The nutrient content of the forest stand is a relatively small part of the total nutrient pool contained in soil. Under the present practices of harvesting stem wood on a 50- to 100-year rotation, nutrient deficiency as a result of crop removal seems unlikely on most forest land. The probability of nutrient deficiency increases as the trend continues toward shorter rotations and more complete utilization of branchwood, thinnings, culls, and brush presently left on the site to nourish forest regeneration after cutting. Nutrient deficiencies that develop as a result of product harvest can be resolved by modifying cutting practices or by fertilization, or both.

This paper was prepared while the senior author was Bullard Fellow at Harvard University. A condensed version was delivered at the annual meeting of the American Institute of Biological Sciences at Amherst, Mass., in June 1973.

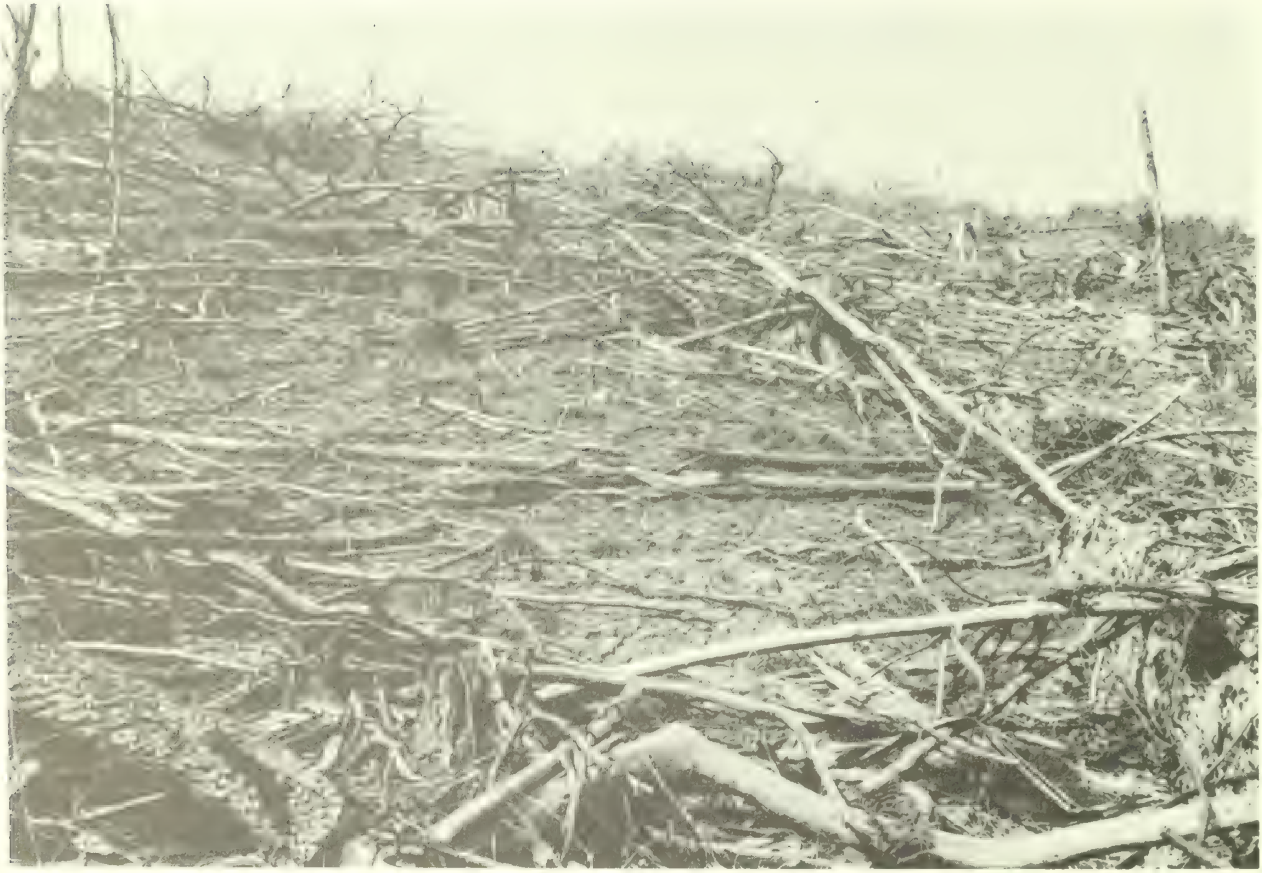

Figure 1.—Many observers see environmental ruin in a conventional clearcut; wasted wood, depleted soil, and polluted streams. Actually, all marketable material had been harvested before this photograph was taken, including logs, pulpwood, and fence posts. (U.S. Forest Service)

Introduction

Theodore Roosevelt once said of forests, "Use them for grazing, for farming, for lumber, for whatever they are best adapted, but so use them that you will not destroy their usefulness for future generations" (*49*). Certainly the eastern deciduous forests have been used, some of them for more than three centuries, and sometimes with little regard for future needs. But today, Roosevelt's ethic is unacceptable to the prophets of environmental crisis, who argue that all but the most conservative forest cutting will lead to "pedological and ecological mayhem" (*12*). Others argue just as vehemently that our nation can ill afford to leave any mature trees uncut (fig. 1), and that the untended forest is an unbalanced ecosystem incapable of providing the goods and services expected from productive wildland (*34*). Foresters hold an uncomfortable middle ground between these idealistic extremes, under fire from one side as the compliant tools of forest industry, from the other as visionary preservationists.

Those who favor minimum cutting foresee soil sterility; those who favor maximum cutting foresee stand stagnation. Although the term seldom is used—indeed, the concept seldom is perceived—both sides tacitly hold that effective nutrient cycling will cease unless forests are managed as they advocate. As used in this paper, "nutrient cycling" means the continuing use and reuse of soil nutrients by forest vegetation. There has been much research pertinent to this subject; there are two good summaries of the older research (*31*, *39*), but more recent papers (*11*, *45*, and especially *43*) provide better overviews of nutrient cycling as it relates to modern forest management.

Interest in nutrient utilization by forest trees is not new. The earliest American study known to us concerned ash analysis of wood, bark and twigs of selected old-growth hardwoods; it was reported by the U.S. Commissioner of Patents in 1850 (*48*). Both the pioneers and most modern students of nutrient cycling would probably accept cheerfully this qualitative statement of 36 years ago: "The amounts of essential mineral constituents in the soil and the amounts used by forest vegetation are such that even soils low in them contain an excess. Apparently, the exhaustion of essential mineral constituents by forest cropping seldom takes place" (*47*). This attitude prevailed until the "environmental crisis" of the past few years thrust into the vernacular such poorly understood catchwords as ecology, biodegradable, clearcutting, recycling, and pollution.

The Nitrogen Cycle

Ordinarily, no nutrient is more deficient in forest soils (*20*) or poses a greater pollution threat than nitrogen. Most abundant of the nutrients, nitrogen is essential for life, but some of its naturally occurring chemical forms can be harmful if present in high concentrations in drinking water (*33*). Although nitrogen is closely recycled in hardwood forests, tree eradication and conventional clearcutting have caused accelerated nitrate leaching from New Hampshire soils (*37*). Nitrate, a common form of soil nitrogen, is a freely diffusible ion in the soil solution and is easily lost by leaching. Because of its importance in the human as well as the forest environment, we will stress the role of nitrogen in nutrient cycling. Other minerals present lesser nutritive and pollution problems, and space does not permit dealing at equal length with them.

A model (fig. 2) provides one way to visualize the nitrogen cycle in forests. Cycles for other nutrients will differ considerably from this one. Note that the atmosphere, soil, and trees constitute sinks in the nitrogen cycle. The atmosphere is considered an inexhaustible reservoir for nitrogen which, in its elemental form, is entirely unavailable to trees. Gaseous nitrogen must be "fixed" in the soil (i.e., combined with oxygen or hydrogen) by any of several naturally occurring processes. Ordinarily, fixed nitrogen taken from the soil by trees is ultimately returned to the atmosphere or to the soil with little net change in the quantities available for tree growth. Fertilizing the forest and harvesting wood products are the usual means by which man modifies this balance; they provide our only important opportunities to influence nitrogen ingress into or egress from the cycle. Lesser nitrogen outgo may ac-

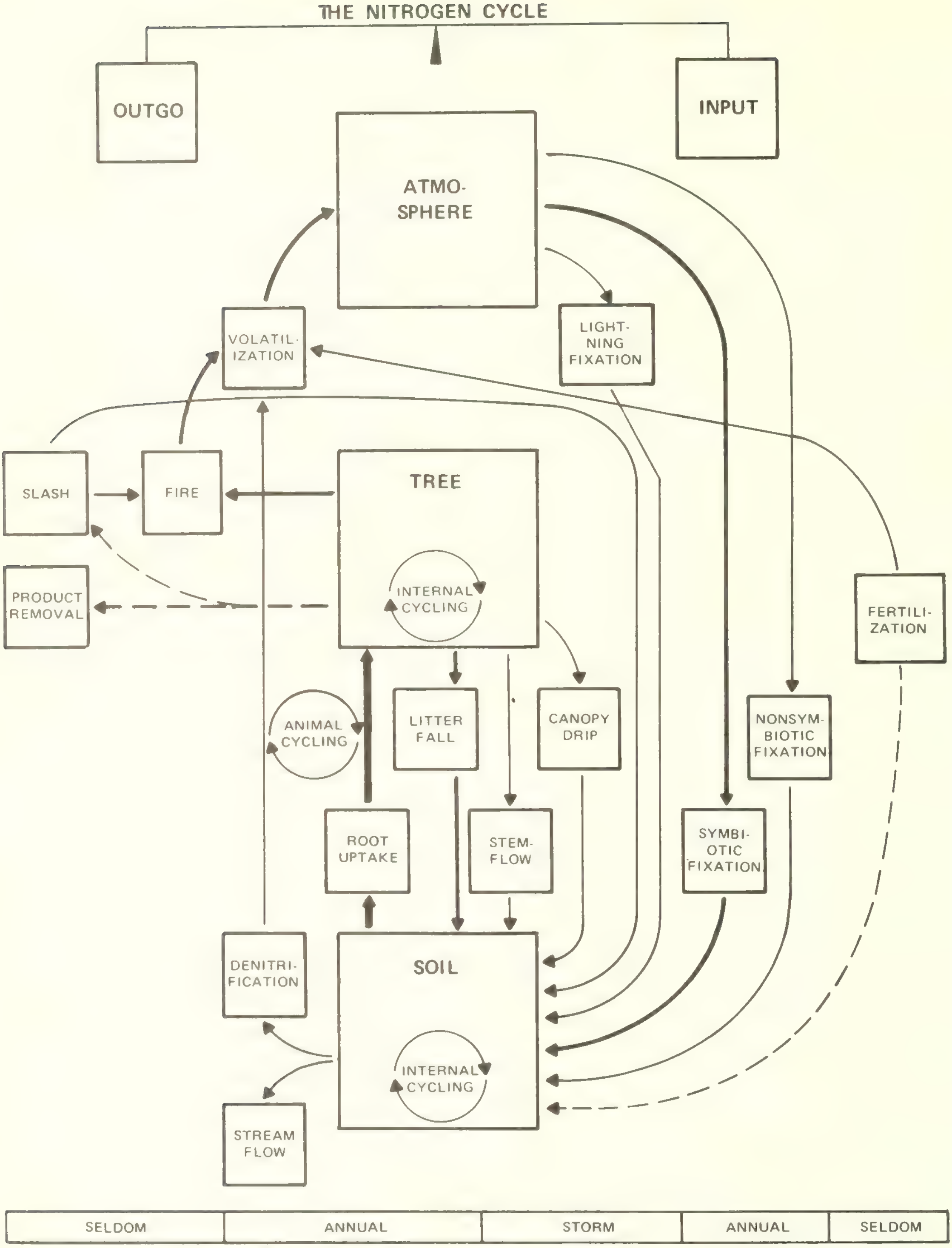

Figure 2.—The nitrogen cycle in the eastern deciduous forest. Several relationships are suggested nonquantitatively in this diagram. (1) The thickest lines imply the most important pathways. (2) Broken lines show nitrogen pathways subject to some control by forest managers. (3) Nitrogen pathways are "stacked" above cycling frequencies to show their recurrence rates. (4) Processes in the right half of the figure (nitrogen inputs to the soil-tree system) remain in long-term balance with processes on the left (nitrogen outgo from the soil-tree system).

company such cultural practices as thinning, controlled burning, or litter removal. Mismanagement, such as permitting repeated wildfire or accelerated erosion, may inadvertently open important avenues of nutrient escape from the cycle. In the future, legumes (either introduced or natural) may be more important as sources of fixed nitrogen, especially in light of the present energy crisis and the impact it may have on N fertilizer production.

Several subcycles of different frequencies make up the overall nitrogen cycle. During storms, modest inputs to the soil occur as stemflow, canopy drip, and washout from the atmosphere. Larger amounts of nitrogen are involved in a more or less continuous annual cycle; here litterfall and fixation by symbiotic and nonsymbiotic processes are the major inputs, while soil nitrogen is lost by root uptake, denitrification, and leaching to streamflow. The essential role of water in cycling nitrogen and any other nutrients must not be overlooked. Physically, water is the major vehicle of nutrient transport in the soil, the tree, and –to a large extent–the atmosphere. Man's major influence on the nitrogen cycle occurs at the "seldom" frequency in well-managed forests. Input by fertilization is especially important because any nutrient can be introduced into ecosystems at whatever time, place, and amount is deemed necessary. Wood product removal is the most common avenue of major nutrient loss from the cycle.

The supply of nitrogen withdrawn from forest soil by trees is replaced from several sources. Atmospheric washout adds from 2 to 10 kg/ha/yr (*40*) with lightning fixation accounting for 10 to 20 percent of this amount (*25*). Other significant sources of atmospheric washout in forests include nitrogen lost from agricultural land and from manufacturing. In agriculture, fixation by legumes ranges from 50 to 100 kg/ha/yr (*34*); however, rates are probably lower in forests, where legumes are relatively scarce. A net gain of 45 kg/ha/yr of fixed nitrogen was reported in a stand containing black locust (*22*). Over 300 species of nonleguminous nitrogen-fixing plants are known (*6*), these having fixative capabilities ranging from 50 to 100 kg/ha/yr (*42*). More recent studies report that the fixative capabilities of nodulated American speckled alder are as high as 168 kg/ha/yr in thickets (*13*) and 85 kg /ha/yr on an abandoned mill pond where it was growing with red maple and paper birch (*52*).

Microorganisms transform important quantities of nitrogen. The blue-green algae are probably most important of the nonsymbiotic nitrogen-fixing microorganisms, with 20 such species known (*17*). However, their role in forest soils of the temperate zone is uncertain. The importance of nitrogen-fixing bacteria in forests is also unknown (*17*). Nitrifying bacteria increased in numbers 18- to 34-fold after forest cutting in New Hampshire and greatly increased humic nitrification (*29*). Russell (*40*) emphasized that biological nitrogen fixation appears to take place in agricultural soils only when the vegetation is not in equilibrium with the soil and climate, or when nitrogen compounds are being removed from the land. In these situations, continuing replacement of nitrogen in forest soils throughout the growing season seems probable.

Nutrients in the Unmanaged Ecosystem

Enormous amounts of nutrients are stored in forest soils (table 1). County soil surveys provide information specific to many locations and often will differ widely from the data in table 1. Such differences must be expected, not only because there is great variation among soils, but also because many different

Table 1.—Average total nutrient content of several forest soils of Connecticut. Adapted from Lunt (30)

Horizon	Horizon thickness	Total nutrients				
		N	P	K	Ca	Mg
	(cm.)	kg/ha/cm				
Organic	5	129	11	303	209	38
A	15	216	83	14	52	64
B	50	86	68	8	8	10
C	30	22	67	7	8	10
		kg/ha				
Profile	100	8836	6725	2334	2470	1967

For those readers unfamiliar with metric units, kg/ha can be regarded as about the same as pounds per acre. The actual conversion equation is lb/ac. x 1.12=kg/ha.

sampling and analytical techniques have been used. For example, forest soils of West Virginia (*2*) differ greatly from those of the Piedmont (*14*) and from those of Connecticut. Actually, the absolute amounts shown in table 1 are of little significance; they serve merely to illustrate the magnitude of nutrient supplies potentially available from one meter's depth of forest soil. Trees usually root profusely in the upper meter of forest soil and often extend much deeper (*27*).

Regolith weathering releases only a little nitrogen but it is a major source of other mineral nutrients. Its importance to trees on any given site is largely speculative. For example, a rate of 800 kg/ha/yr for weathering of silicate materials was calculated for New Hampshire, releasing about 4 kg/ha/yr of potassium, and about 8 of magnesium.[1] The whole-earth weathering rate for bedrock has been estimated at 270 kg/ha/yr (*4*). Apparently, there is little gain or loss of soil phosphorus in the deciduous forest (*42*). Some nutrients are released through slash decomposition and burning, although much of the nitrogen is released into the atmosphere in gaseous forms. Insects and disease organisms probably hasten the return of nitrogen and other nutrients to the soil, but effect little gain or loss to ecosystems. A variety of compounds are added to soils by mortality of small roots, many of which probably live for no longer than a year (*26*). Other nutrients—organic and inorganic—are added by root exudation (*44*).

Forest trees contain far less nutrients than do the soils that support them (table 2). These data describe a carefully analyzed deciduous forest in Belgium; however, the amounts of phytomass and nutrients seem consistent with less thoroughly documented deciduous forests in the eastern United States. A few generalizations drawn from these data probably are applicable throughout the hardwood region: The harvested stem, about half of the forest phytomass, includes about one-third of the nutrients contained in forest trees. The remaining two-thirds of the mineral nutrients are contained in the unharvested half of the tree's phytomass, its extremities. Similar nutrient distribution has been observed in Maine (*62*) and in Canada (*18*). Bark is richer in nutrients than wood (*61*), branch wood more so than stem wood (*7*). The understory and other minor forest vegetation seldom comprise more than 5 percent of the phytomass (*57*) or nutrient content (*15*) of fully stocked mature stands on good sites. Stand age, species composition, and stage of succession also influence nutrient content (*60*). To generalize, conventionally unharvested tree parts are about twice as rich in nutrients as tree parts normally removed from the forest site.

The most comprehensive account known of nutrient cycling in an American deciduous for-

Table 2.—Nutrient distribution in tree components of a mature deciduous forest in Belgium. Adapted from Duvigneaud and Denaeyer-DeSmet (15)

Components	Phytomass	Nutrient Content					Ratio of nutrient content to phytomass
		N	P	K	Ca	Mg	
		——————kg/ha——————					
Stem wood	64,522	95	7	73	77	23	1:235
Stem bark	8,760	44	3	21	328	19	1:21
Branch wood	24,201	56	5	34	49	9	1:158
Branch bark	6,757	48	3	17	207	13	1:23
Twigs	4,947	40	3	13	79	6	1:35
Leaves	3,458	73	5	36	54	5	1:20
Roots	34,600	127	12	97	380	19	1:54
Totals	147,245	483	38	291	1174	94	

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[1] Singer, M. and R. H. Rust. 1972. Phosphorus cycling in an east-central Minnesota deciduous forest. I. Biomass and phosphorus content of the natural system. Unpublished report, School of Forestry, University of Minnesota, St. Paul.

est (table 3) comes from North Carolina (*56*). These data suggest that yearly nutrient input is sufficient to replace all nutrients in the entire forest phytomass within 10 years. There are surprisingly large expanses (*58*) of nutrient-rich bark (1.5 to 2.8 m^2/m^2 of ground surface) and of leaves (3 to 6 m^2/m^2 of ground surface) from which nutrients can be washed as stemflow (*19*) or as canopy drip. Soil-nutrient input in North Carolina hardwoods substantially agreed with that in the Belgian forest; even though the former stand was a little older and somewhat less densely stocked, it had larger trees.

No published account is known of nutrient balance in an American deciduous forest; however, the following data for the deciduous forest in Belgium (table 4) probably are representative of American conditions. For nitrogen at least, this tabulated annual return (62 kg/ha) seems minimal because it did not, indeed could not, allow for nitrogen biologically fixed during the growing season. By the same token, the tabulated amounts for all other elements returned to the soil probably are conservative estimates because no quantities were allowed for mineral weathering. Thus, it is clear that forest trees actually retain only a rather modest portion of the nutrients taken from the soil.

Table 3.—Replenishment of soil nutrients in a North Carolina hardwood forest. Adapted from Wells, et al. (56)

Source	Nutrients (kg/ha)				
	N	K	P	Ca	Mg
Rainfall	3.53	0.28	0.88	3.42	0.72
Canopy drip	4.86	0.61	17.48	12.47	3.75
Stemflow	0.23	0.01	0.65	2.02	0.24
Litter	45.98	3.26	14.16	94.99	18.11
Annual input to soil	54.60	4.16	33.17	112.90	22.82

Table 4.—Annual nutrient balance of a mature deciduous forest in Belgium. Adapted from Duvigneaud and Denaeyer-De Smet (15)

Nutrient disposition	Nutrient				
	N	P	K	Ca	Mg
	————kg/ha/yr————				
Taken from soil by trees	92	6.9	69	201	18.6
Returned to soil in rain and litterfall	62	4.7	53	127	13.0
Retained in forest tree biomass	30	2.2	16	74	5.6

Some Effects of Forest Management on Nutrient Cycling

As previously noted, fertilization (the deliberate addition of needed nutrients) is the only management technique by which man introduces large amounts of new nutrients into the forest cycle. Fertilization is done in many ways; the oldest measures used in forestry were biological and were celebrated thus in 1630 (*46*):

> "The alder, whose fat shadow nourisheth,
> Each plant set neere to him long flourisheth."

Nitrogen-fixing plants help bring about an astonishingly quick revegetation of extremely disturbed sites. For example, after glacial retreat in Alaska, alder quickly becomes established on newly exposed, sterile gravel, then is succeeded by Sitka spruce about 20 years later. After the leguminous tree, black locust, is established on strip mine spoil banks in the Ohio Valley, invasion by nonleguminous hardwoods follows within a few years (*9*). Despite their demonstrated value, such biological methods involve considerable time and labor and are seldom used in conventional forestry.

Sometimes a dual purpose is served when farm manure, certain factory wastes, or partially treated municipal sewage are spread on forest land. Sewage effluent, at least that containing low concentrations of heavy metals, can be so disposed of safely and without insult to the environment. Soil moisture is maintained at high levels, and forest growth is greatly stimulated by both the continuous water supply and the added nutrients. An experiment started in 1963 at the Pennsylvania State University thoroughly documents the disposal of secondary-treatment sewage and some of its effect on the nutrient balance of hardwood forests and the underlying soil (*41*). Many communities are taking a hard look at this possible solution to their sewage-disposal problems.

Unquestionably, aerial application of commercial fertilizers is the most efficient way to adjust the nutrient balance of forest ecosystems. Fertilization may also be helpful in preventing erosion on harsh sites and for enhancing wildlife habitat. Some biologic advantages of fertilization in terms of increased hardwood production have been reported (*8, 24*). Forest soils generally are deficient in nitrogen (*20*) but greatest tree growth often follows application of two or more nutrients (*3*). Moreover, different tree species often differ in their nutrient requirements and in their responses to fertilization (*51*). Existing knowledge of the ecological consequences of forest fertilization has been reviewed (*5*) but much remains to be learned. Greater economic incentives as well as more research are needed before large-scale fertilization is undertaken in eastern hardwoods.

To date, studies of nutrient cycling in fertilized hardwoods have not been comparable in numbers or in completeness to those in conifers. Some preliminary results, however, are available from a pioneer experiment in hardwood forest nutrient cycling at the Fernow Experimental Forest near Parsons, West Virginia. Nitrogen as urea was applied by helicopter on a calibrated watershed at a rate of 224 kg/ha. This rate was estimated to be the amount required to greatly increase tree growth without toxic effects. Estimates based on 643 water samples indicate that over 50 kg/ha of nitrogen, in both nitrate and ammonium form, were lost in streamflow during the first year after fertilization (*1*). This nitrogen loss was accompanied by increased concentrations of Ca, Mg and K in streamflow (*1*). Volatilization losses were sufficient to cause a distinct ammonia odor, but no attempt was made to quantify these losses. In Florida, less than 10 percent of a 100 kg/ha urea application was lost as gaseous NH_3 (*53*). Nitrogen content of the vegetation increased measurably but these data are insufficiently processed to report on an areal basis. Experience elsewhere suggests that much of the applied nitrogen has been incorporated more or less permanently into the ecosystem and that losses to streamflow and to volatilization would have been less given lighter fertilization, different N sources, or different weather conditions.

Removing wood and bark from its site of growth accounts for most nutrient drain on forest land. The oft-told tale of reduced tree growth following centuries of litter removal in Germany (*54*) neatly illustrates how such problems can develop. Posassium deficiency in some northeastern soils is ascribed to the use of deciduous forests as a source of potash during Colonial times.[2] Nutrient deficiencies may accompany monocultures and type conversions, but management of this kind is rare in hardwoods. Severe forest grazing invites the same problems but this malpractice, as well as litter removal, is so rare in the deciduous forest as to pose a negligible nutrient drain. Fire, once considered a major agent of soil deterioration (*47*), now is regarded more as a determinant of species composition, in hardwood (*10*) as well as in coniferous forests. For example, burning has a relatively small effect on soil nutrient content in the southeastern coastal plain (*55*), whereas fire-caused mortality sets back young hardwood growth from 4 to 7 years (*28*). Road building and accelerated soil erosion undoubtedly provide another avenue of nutrient drain, but the amounts of such loss are not reported. While on this subject, we wish to emphasize that properly performed clearcutting of hardwoods causes no overland flow during heavy rain (*36*), therefore cannot cause accelerated soil erosion or the associated loss of soil nutrients (*50*). This point must not be confused with Pierce's (*37*) observations concerning mineral losses through, not across, the soil on clearcut land in New Hampshire.

The removal of wood products causes most nutrient loss from conventionally managed forest land. Actual measurement of products so harvested provided a real-life basis for estimating this loss (table 5). These data probably are representative of nutrient drain from most hardwood forest land as currently managed. They were obtained from several experi-

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[2] Personal communication from G. W. Bengtson, Muscle Shoals, Alabama.

Table 5.—Estimated nutrient losses accompanying wood product removal from the Fernow Experimental Forest, Parsons, W. Va.

Practice	Cutting cycle[a]	Harvested phytomass	Nutrients[b] removed from soil[c] per cycle	Nutrients[b] removed from soil[c] per year
	(yr.)	kg/ha	kg/ha	kg/ha
Intensive selection (selected trees over 12.5 cm dbh)	5	10,323	98	20[d]
Extension selection (selected trees over 27.5 cm dbh)	10	22,237	180	18
Diameter limit (all salable trees over 43 cm. dbh)	20	25,221	236	12
Commercial clear-cutting (all salable trees over 12.5 cm dbh)	75	51,030	473	6
Liquidation cutting (all salable trees branches and culls)	75	94,295	892	12

[a] Frequency of recutting
[b] N, P, K. Ca, Mg
[c] Computed as 88 percent of the harvested phytomass as wood, 12 percent as bark; applying nutrient content to phytomass ratios for stemwood and bark as shown in Table 2.
[d] Nutrients removed from soil per cycle ÷ years in cutting cycle.

mental watersheds in West Virginia, ranging in area from 14 to 36 ha. The stands consisted of 50- to 60-year-old second growth with residuals from a heavy cutting in 1905. Predominant species were oaks, maples, yellow-poplar, black cherry, and beech. Volumes ranged from 127 to 218 m^3/ha with both sawtimber and pulpwood harvested. About half of the nutrients contained in above-ground phytomass of a mixed-oak stand were estimated to have been removed in commercial logs during clear-cutting in Pennsylvania (*59*).

Note that repeated light cuts tended to cause greater average annual nutrient drain than did a single cut per rotation. This greater drain was caused by harvesting the smaller and weaker trees that are likely to die in less intensively managed stands; their decay assures considerable nutrient return to the site. At present, economics dictates the desirability of less intensive management, aiming to produce a relatively few trees with high market value and thus posing no real threat to continuing site productivity. This situation will change if there is a profitable market for products now of no economic value and presently left in the woods. Then, more frequent cutting and closer utilization with correspondingly greater nutrient drain must follow. For example, the use of presently noncommercial brush species for pulpwood will cause about the same nutrient drain as does the present harvest of commercial tree species (*16*). Increased utilization of boles, tops, and branches of hardwoods (fig. 3) is likely to double the present nutrient removal (*7*). These portions of harvested trees now are left on the ground to replenish soil nutrients, mostly because they have no other value—yet foresters are criticized for "wasting" this wood. Their critics do not believe that it is uneconomic to harvest such material, nor do they realize that, left in place, unharvested tree parts help to replenish soil fertility. Furthermore, slash removal from the forest raises other environmental questions. Intensive harvesting of small products could increase forest soil erosion and will concentrate nutrient-rich branch wood and bark near manufacturing centers already overloaded with wastes. A very close look at nutrient cycling and environmental problems is warranted if the concept of whole-tree harvest is applied on a large-scale, short-rotation basis in the eastern deciduous

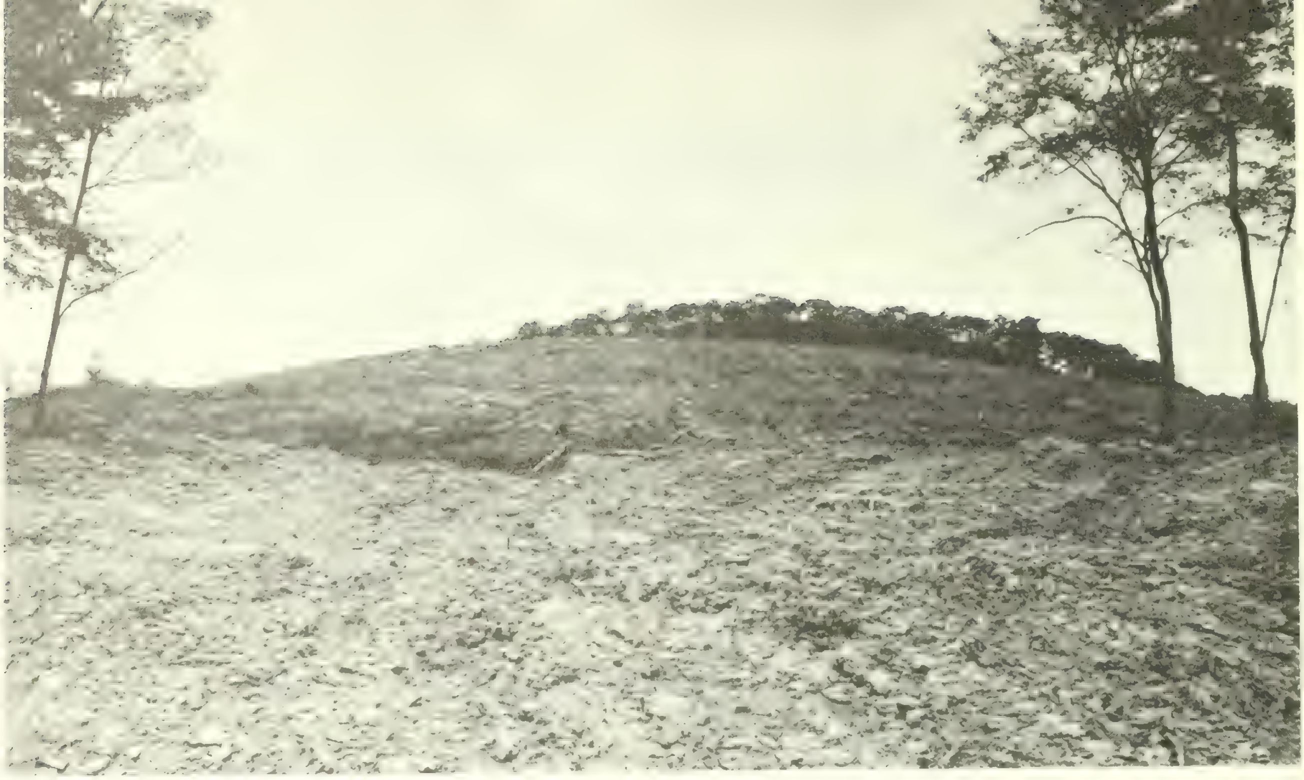

Figure 3.—The uncluttered look of this scene appeals to many observers. But despite its greater esthetic appeal, complete removal of slash and residue may lead to depletion of the soil as nutrients are removed from the cycle.

forest. Several such operations are already being successfully conducted on a pilot basis by industry and there is little doubt that whole-tree utilization will become a standard harvesting technique.

Discussion

There is a pronounced tendency in the literature to place more weight on nutrient outflow from forest soil than on its replacement, probably reflecting the common idea that man is the only disturbing element in an otherwise perfect forest scene. Disregarding the philosophical implications of this attitude, there may be good reason for such bias. Nutrient outflow is far more easily visualized than is nutrient replacement. Harvested wood not only is visible but is routinely measured. The accompanying nutrient loss is easily estimated—and deplored—from these figures. Natural nutrient replacement is a wholly invisible process. A related attitude contributes to this bias, the general belief that forest soils are low in fertility. True, many forest soils cannot meet the exacting fertility needs of farm crops, but it hardly follows that further wood harvest will exhaust their store of nutrients. Nutrients available to trees in forest soils often have been underestimated, investigators having restricted their estimates of availability to the surface 15 cm of soil; but trees are widely known to root far deeper. Others have recognized the importance of such processes as the chemical breakdown of parent material and the bacterial transformations of nitrogen but few seek to quantify these less visible, less easily measured processes or to assess the stimulating effects of timber harvest on them.

There is another, related facet to this problem. The soil sometimes is envisioned as containing X amount of nutrients; timber harvest removes 0.5X; ergo, two timber harvests will exhaust the soil fertility. This concept of the nutrient supply, analogous to the water supply for flowers in a vase, is not only useless but needlessly alarming. It wholly fails to account for changing availability or continuing replenishment. Some nutrients (e.g., phosphorus) may be relatively abundant in an unavailable form. When available phosphorus is depleted, natural conversion to an available form soon begins. For another example, nitrogen fixation is more rapid during nitrogen scarcity than when nitrogen is abundant in soil. Furthermore, nutrient use by trees does not proceed at a constant rate as soil fertility declines, but decreases gradually as nutrients are depleted. Nutrient stress does not develop without reduced growth rates and other warning signs, providing ample time to relieve the stress by fertilization or by modifying cutting practices. We do not dismiss the possibility of reduced forest soil fertility; we do not invoke much research and experience to assert that such problems are most unlikely to develop under rational forest management. To cite a single example: after centuries of intensive use, Germany's Black Forest continues to produce high yields of wood and otherwise provides ample justification for our optimism.

Above and beyond all of these technical matters, there is a general failure to appreciate the tremendous resilience that allows forest vegetation to survive many temporary derangements of a presumably constant nutrient supply. Here arises the concept of the steady state, heavily relied upon in many studies of nutrient cycling, but liable to overliteral interpretation. Most of the eastern deciduous forest has been cut over from one to several times. Much of it has been cleared at least once for agriculture. Much has burned from time to time and all of it is subject to windthrow, disease, and defoliation of varying severity. Superimpose on these recurring hazards the edaphic, microclimatic, and topographic irregularity of most forest land. Add the species and size diversity characteristic of the deciduous forest; then confound this complex picture with man's ubiquitous forest activities: a most unsteady state of nutrient cycling is easy to envision. Undeniably, the steady state is a useful concept; so is the average man, but one would be poorly advised to invest much time or money in quest of either one.

Forest occurs on the headwaters of most streams, especially in mountainous terrain, where yet another aspect of nutrient cycling, and of the steady state, merits comment. Here, the variable source area concept of streamflow (*21*) pertains, in which watershed soil is seen as the ultimate origin of streams. Rain that infiltrates into hilly land moves downslope through the soil until, driven by gravity, it finally emerges in seeps and springs to form headwater streams. The implications of the source area concept on the nutrient cycle are great, because a mechanism is envisioned for nutrients dissolved upslope to nourish trees downslope, or if uptake by trees is precluded, ultimately to be flushed from the ecosystem. Since the extent of source areas and their drainage rates vary primarily with rainfall, their actual influence on nutrient distribution is virtually unmeasurable. Nevertheless, this movement probably accounts for the relative impoverishment of ridge soils and the relative richness of streamside soils. Furthermore, it suggests that the mineral composition of trees of the same species may differ according to their position, be it on a ridge or near a stream.

The Hubbard Brook study (*37*) embodies the most thorough and far-reaching research on nutrient cycling yet undertaken. But sometimes its results are misapplied (*12*), the accelerated outflow of soil fertility from a deforested watershed being interpreted as evidence that soil sterility would follow any but the most conservative of forest cutting. Actually, the Hubbard Brook results have little relation to nutrient outflow after conventional forest cutting elsewhere in the East, as the loss of nutrients appears to be negligible from podzol (*50*) as well as most nonpodzol soils (*38*).

Too little has been made of a far more useful outcome of the original Hubbard Brook study (*29*) which, in effect, removed the "tree sink" depicted in figure 1. By cutting the forest and preventing regrowth, we gained, for the first time, some insight into the enormous amount of nutrients available to a new generation of forest trees. The cutting and herbicide treatment was, in effect, a planned disaster. Consider the events that followed—greater soil moisture, increased soil temperature, better aeration, and increased chemical and biological activity in the freshly exposed forest floor. Fallen trees and foliage decomposed to augment nutrients also being released from decay-ing litter. Given normal forest conditions, these events would provide optimal nutrition for seedling and sprout growth. But preventing regrowth with herbicides prevented all nutrient uptake and some of these decay-released materials were lost from the ecosystem via streamflow.

We interpret these results as evidence, not of damaging loss of soil fertility accompanying timber harvest, but of a survival mechanism to assure vigorous regrowth after disaster, whether man-caused or natural. When a pioneer stand finally was allowed to develop at Hubbard Brook, substantial loss of soil fertility ceased and nutrients were stored in pin cherry for subsequent use by the more permanent stand that followed (*32*). This experiment thus demonstrates a "shot-in-the-arm" effect following disaster, in which massive nutrient releases probably stimulate reforestation. Lesser nutrient releases probably stimulate regrowth similarly on land under more conventional forest management.

Conclusions

Obviously, much remains to be learned about nutrient cycling in the deciduous forest. The International Biological Program will help to meet this need, with a vast amount of new information even now being readied for publication. The following conclusions can be regarded as little more than tentative until they are refined in light of this new knowledge.

I. It is unlikely that any conventional forest cutting poses an immediate threat to continued forest soil productivity.

II. Presently unconventional practices, such as whole-tree harvest, can pose a threat to continuing forest productivity. Continuing assessment of tree nutrition should accompany shorter cutting rotations and more complete tree utilization.

III. Nutrient release during periods of intermittent forest floor exposure provides an important mechanism for forest survival.

IV. Should nutrient deficiencies develop, modern technology now permits their solution through a combination of fertilization, modified harvest practices, and regeneration methods.

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The literature was reviewed for reports on nutrient cycling in the eastern deciduous forest, particularly with respect to nitrogen, and on effects of forest management on the nutrient cycle. The nutrient content of the forest stand is a relatively small part of the total nutrient pool contained in soil. Under present practices of harvesting wood on a 50- to 100-year rotation, nutrient deficiency as a result of crop removal seems unlikely on most forest land.

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HOW LONG DO PEOPLE
Look at and Listen to
FOREST-ORIENTED EXHIBITS?

USDA FOREST SERVICE RESEARCH PAPER NE-325
1975

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

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HOW LONG DO PEOPLE Look at and Listen to FOREST-ORIENTED EXHIBITS?

ABSTRACT

To gain a better understanding of public reaction to I & E displays, average visitor-viewing time was measured for a variety of exhibits at the Adirondack Museum, Blue Mountain Lake, N.Y. Visitors viewed displays 15 to 64 percent of the time required to read or listen to the total message presented. The longer the message per exhibit, the less time was spent observing it. This paper includes a picture of each exhibit, the number of minutes normally required to read each exhibit's entire message, and the average number of minutes visitors actually took to view each display. Study results are intended to assist professionals in the design and presentation of I & E exhibits about people's relation to their forest resources.

INTRODUCTION

INFORMATION AND EDUCATION (I & E) exhibits can serve to help us understand our use of the forest—not only as a unique renewable resource but also as an outdoor playground. However, do people really read, hear, and understand the messages presented at I & E displays about people's relationship to their forest environment?

The purpose of our study was to describe differences between required reading or listening times for a variety of I & E exhibits and the time people actually spent reading and listening to the exhibits. Study results may help forest recreation managers and I & E personnel:

- To better understand public reaction to museum displays.
- To improve descriptions of future displays, and thus increase the likelihood that the entire message will be read or heard.
- To better inform the public of their affect upon and interrelationship with the physical and cultural aspects of their forest environment.

THE STUDY

Our study was made in 1968 at the Adirondack Museum, Blue Mountain Lake, New York. The museum, one of the finest of its kind in the nation, is located near the geographic center of the Adirondack Region in northeastern New York. Open to the public throughout the summer and early-fall tourist season, the museum contained, at the time of this study, 41 separate indoor and outdoor exhibits.

On three randomly selected days in August and October, we recorded the viewing times, sex, and approximate age categories of randomly selected visitors at each of 14 selected exhibits. The total number of visitors per day during the three sampling days in August ranged from 810 to 1,193; and in October from 100 to 558. On the average, during both months, visitors stayed in the museum a total of 1½ hours.

Before observing viewer behavior, we measured the total time required to read or listen to all the printed or recorded commentary at each of the 14 exhibits used in the study. For a standard of required reading time, we had 10 adults read the entire message at each exhibit, recorded the time they took, and computed an average reading time for each exhibit. Required listening time was measured from the recorded message.

A "t" test was used to determine if average viewing time for the 30 viewers per exhibit in August differed significantly from the average viewing time in October.

Each of the 14 exhibits is described briefly. Signs throughout the museum-campus suggested the most convenient route for visitors to take. The 14 exhibits included in the study are discussed in that sequence.

THE EXHIBITS

Relief Map

Just inside the museum's main building is a 5 x 5 foot topographic relief map of the Adirondack Region. Along one edge of the display's raised platform is a control panel, on which visitors may press various buttons to light up and locate prominent features in the Adirondacks (fig. 1).

Geologic History

Also in the foyer of the main building, and directly between the two entrance doors, six small paintings depict the geologic history of the Adirondack Mountains (fig. 2).

Paintings of Wildlife and Vegetation

A large painting of wildlife species and vegetation in the Adirondacks adorns one wall of the main building foyer (fig. 3). On the opposite wall a painting characterizes water-oriented Adirondack wildlife and vegetation (fig. 4).

Dioramas

In one wing of the main building, a series of dioramas illustrates historical aspects of logging operations in the Adirondacks. At each diorama, earphones enable viewers to hear a recorded message that describes the events presented (fig. 5).

Viewing times were averaged for five dioramas: interior of a logging camp's living quarters, peeling and cutting hemlock trees for bark, skidding and rolling logs on a skidway, removing bark from logs on a lake, and sprinkler wagon and sled of logs.

View of Adirondack Landscape

A diorama-shaped exhibit at one end of the diorama room is actually a window through which visitors may gaze at Blue Mountain Lake — a picturesque island-studded lake that played an important role in the early history of man's adaptation to the Adirondack wilderness (fig. 6).

Cross Section of Log

In the center of the diorama room, the cross section of a 230-year-old white pine tree is exhibited, and a sign relates the age of the tree to historical events that occurred between 1728 and 1956 (fig. 7).

Paintings

In a second wing of the main building, 42 Currier and Ives prints depict man's early life in the Adirondacks. Interpretive signs are interspersed among the prints (fig. 8).

Hermit's Cabin

Next on the museum tour, an Adirondack hermit's 4-foot high cabin, firewood tepee, and utensils are displayed. This outdoor exhibit is supplemented by a sign that describes the hermit's wilderness activities (fig. 9).

Firearms

Near the hermit's cabin, hunting rifles and guns are displayed in an unheated building.

The gun exhibit progresses from antique firearms to modern repeater rifles. A diorama that describes illegal killing, or "jacking," of deer also is included in this exhibit (fig. 10).

Antique Vehicles

Next on the tour, an unheated building contains 11 vehicles used in the Adirondacks before and near the turn of the century. An 1890 hearse, a fire-hose cart with hand pumper, a 1907 Maxwell automobile, and several antique wagons and surreys are included in this exhibit (fig. 11).

Antique Logging Equipment

Vehicles used for logging and road maintenance in the Adirondacks during man's early logging operations were examined next (fig. 12).

Historic Photographs

A variety of black and white photographs depicting life in the Adirondacks during the late 1800s and early 1900s followed. Visitors viewed a belt-mechanism, protected by a glass-enclosed rectangular shaped table, that displayed a variety of scenes showing man's relationship to Adirondack environments (fig. 13).

Canoes and Guideboats

The final exhibit was a collection and display of various types of canoes and guideboats that were used by early settlers and sportsmen in the Adirondacks (fig. 14).

RESULTS

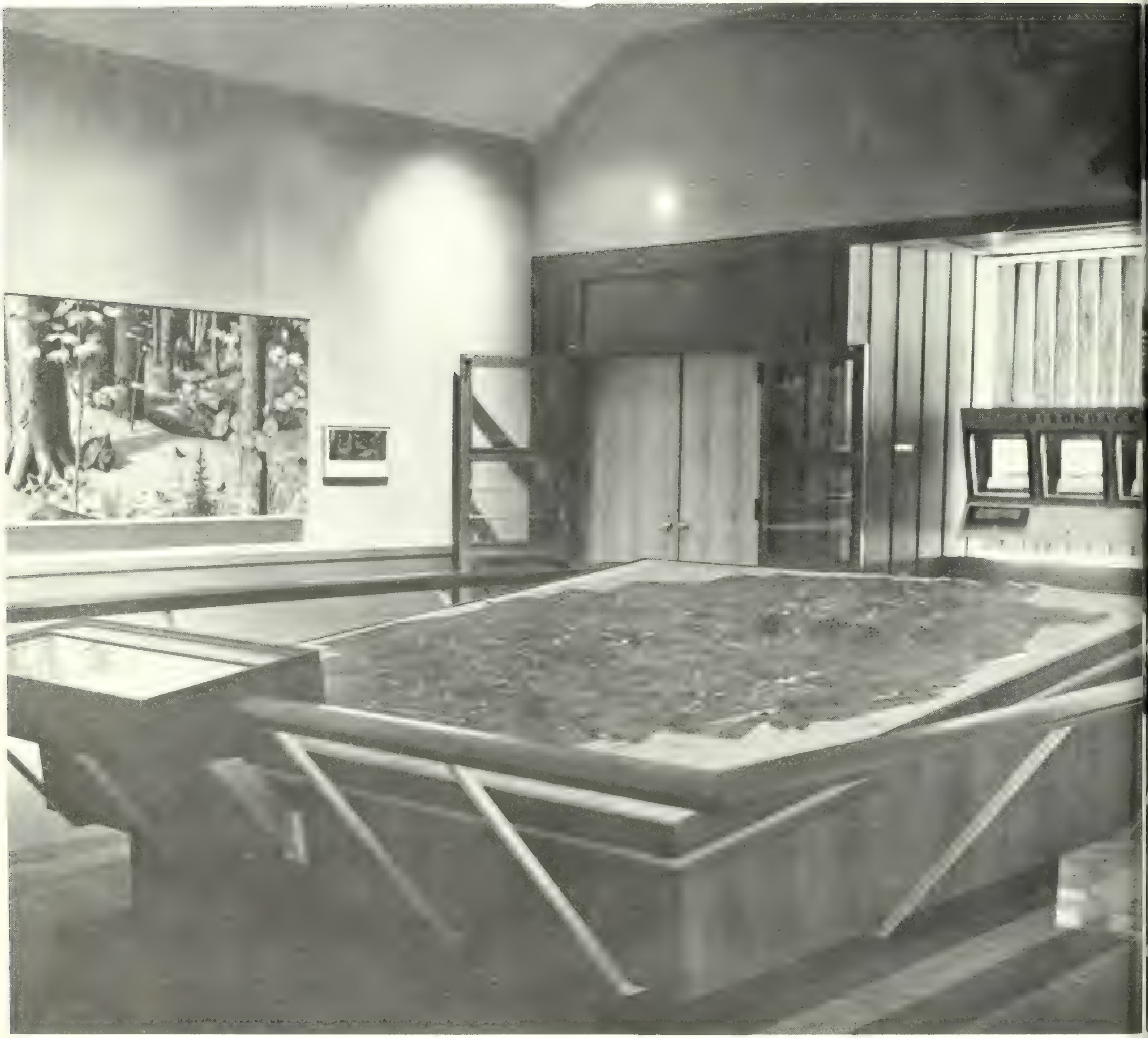
Observations of respondent viewing time indicated that visitors looked at displays only 15 to 64 percent of the total time required to read or listen to the total message presented. Usually, the longer the printed or recorded message a display contained, the shorter the viewing time. Furthermore, August visitors, who were mostly family groups, stayed at exhibits significantly longer or shorter lengths of time (depending on the exhibit) than October visitors, who were primarily older adults.

The exhibits that the viewers saw are shown in the pictures that follow. Below each picture, the following statistics are presented:

- The actual average number of minutes required to read or listen to the entire printed or recorded message.
- The average number and range of minutes that visitors viewed each display.
- The percentage of average required viewing or listening time that visitors used.

Average viewing time per exhibit is reported for the 2 months only when there was a statistically significant difference between them.

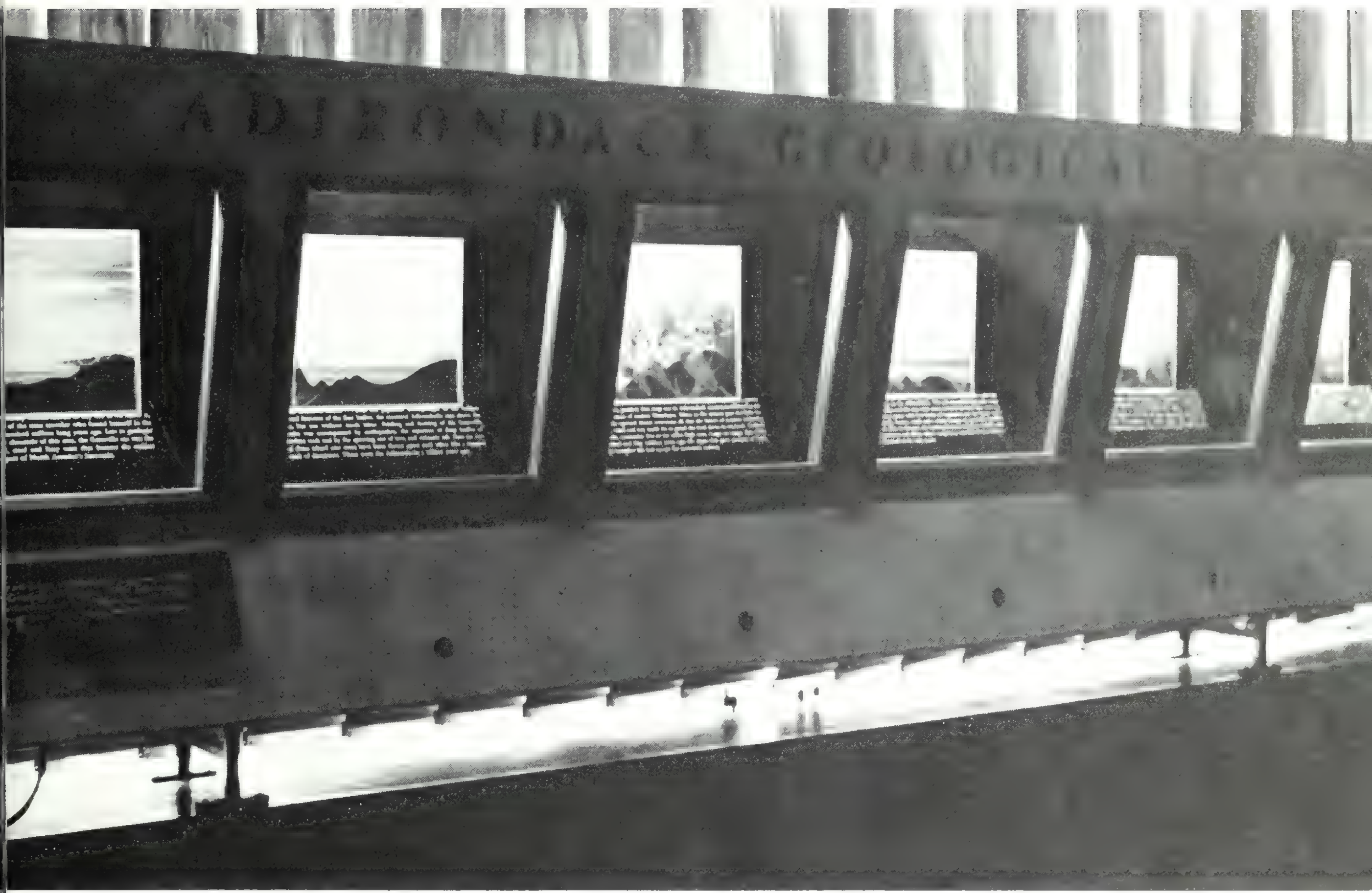
Figure 1.—Relief map of the Adirondack Region.



Average time required to read or listen to the entire message	Average time visitors took to view the exhibit		Average percentage of required reading and listening time that visitors used	
	August	October	August	October
Minutes	*Minutes*	*Minutes*	*Percent*	*Percent*
5.3	1.6	2.3	30	43

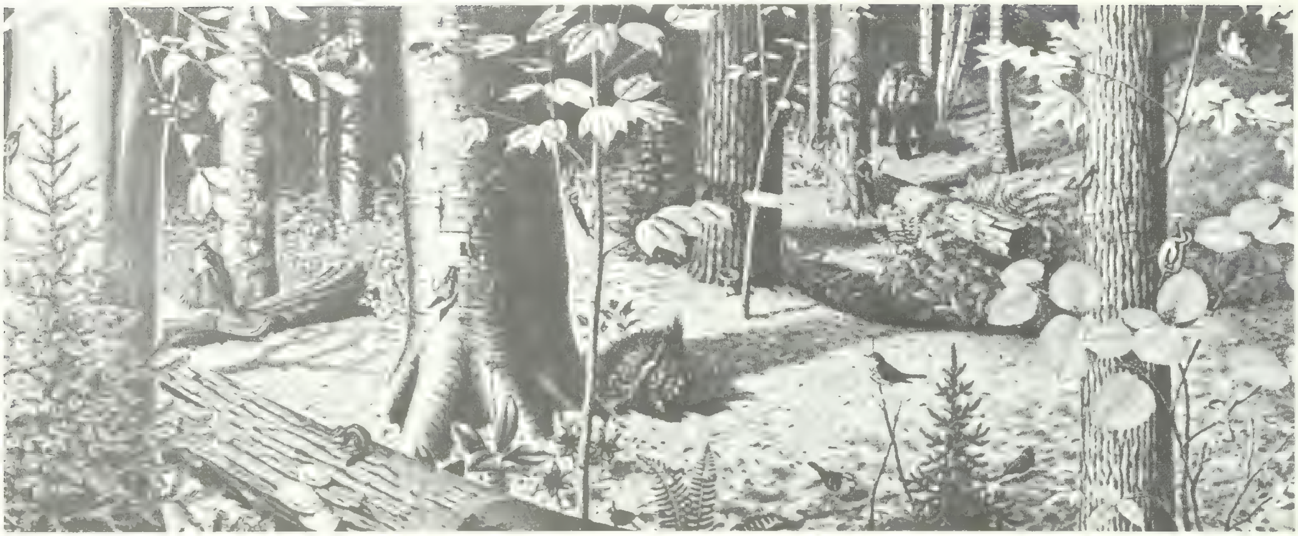
Range of viewing times, in minutes	
August	*October*
0.4 to 4.5	0.2 to 5.4

Figure 2.—Geologic history of the Adirondacks.



Average time required to read the entire message	Average time visitors took to view the exhibit	Average percentage of required reading time that visitors used
Minutes 3.1	*Minutes* 2.0	*Percent* 62
	Range of viewing time, in minutes 0.1 to 4.4	

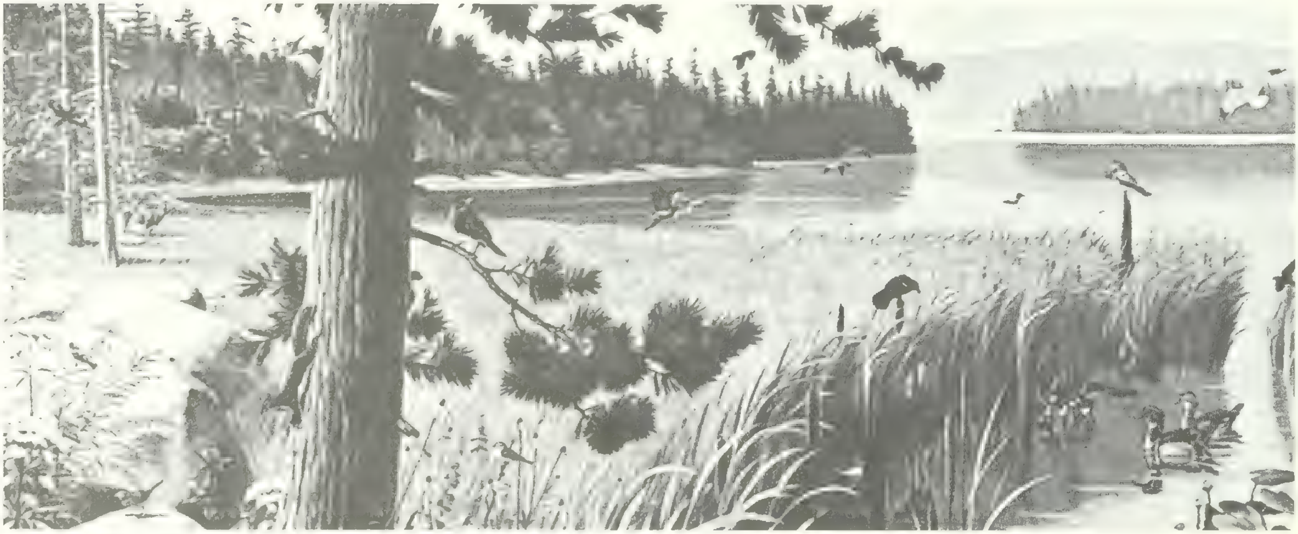
Figure 3.—Woodland painting.



Average time required to read the entire message	Average time visitors took to view the exhibit	Average percentage of required reading time that visitors used
Minutes	*Minutes*	*Percent*
4.5	1.1	25

Range of viewing time, in minutes
0.1 to 5.2

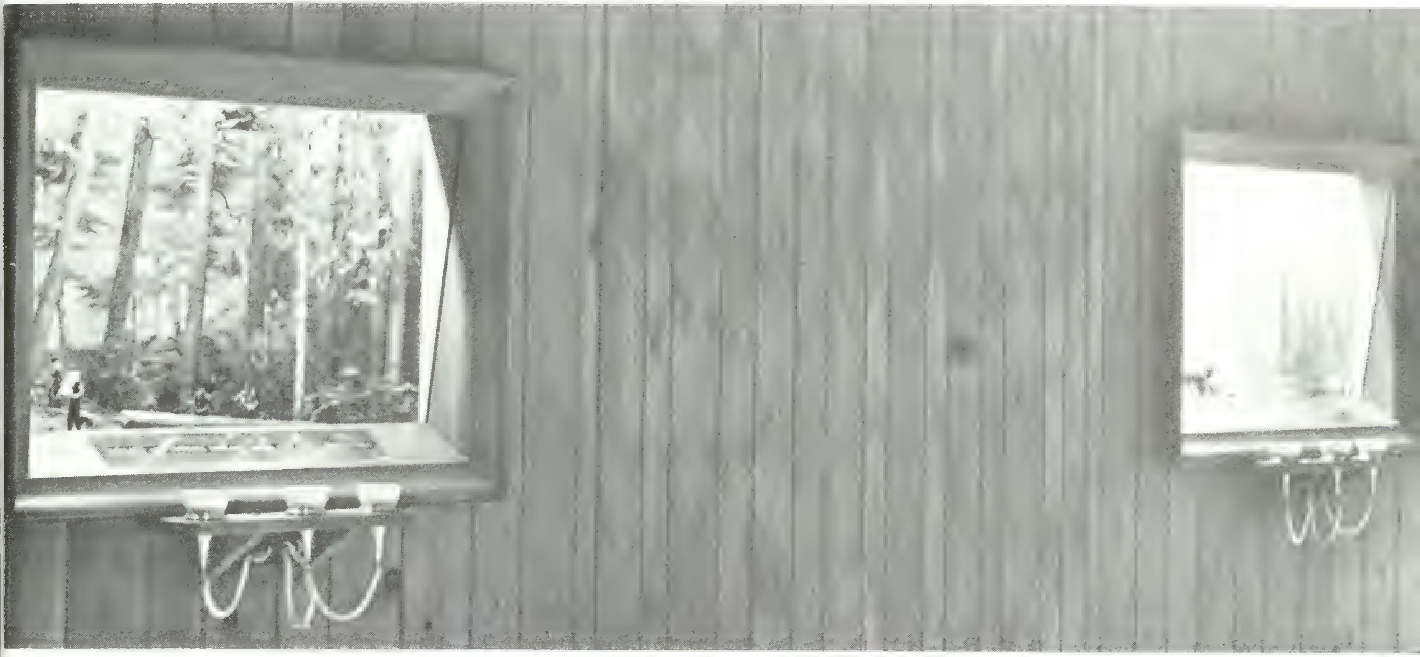
Figure 4.—Lake painting.



Average time required to read the entire message	Average time visitors took to view the exhibit	Average percentage of required reading time that visitors used
Minutes	*Minutes*	*Percent*
2.7	1.0	37

Range of viewing time, in minutes
0.1 to 5.4

Figure 5.—Part of diorama room. Note the three earphones at the bottom of each diorama, which can be used to listen to a recorded message about the scene.



Average time required to listen to the entire message presented at five dioramas	Average time that visitors listened to the messages at five dioramas	Average percentage of required listening time that visitors used at the five dioramas
Minutes	*Minutes*	*Percent*
11.2	4.1	37

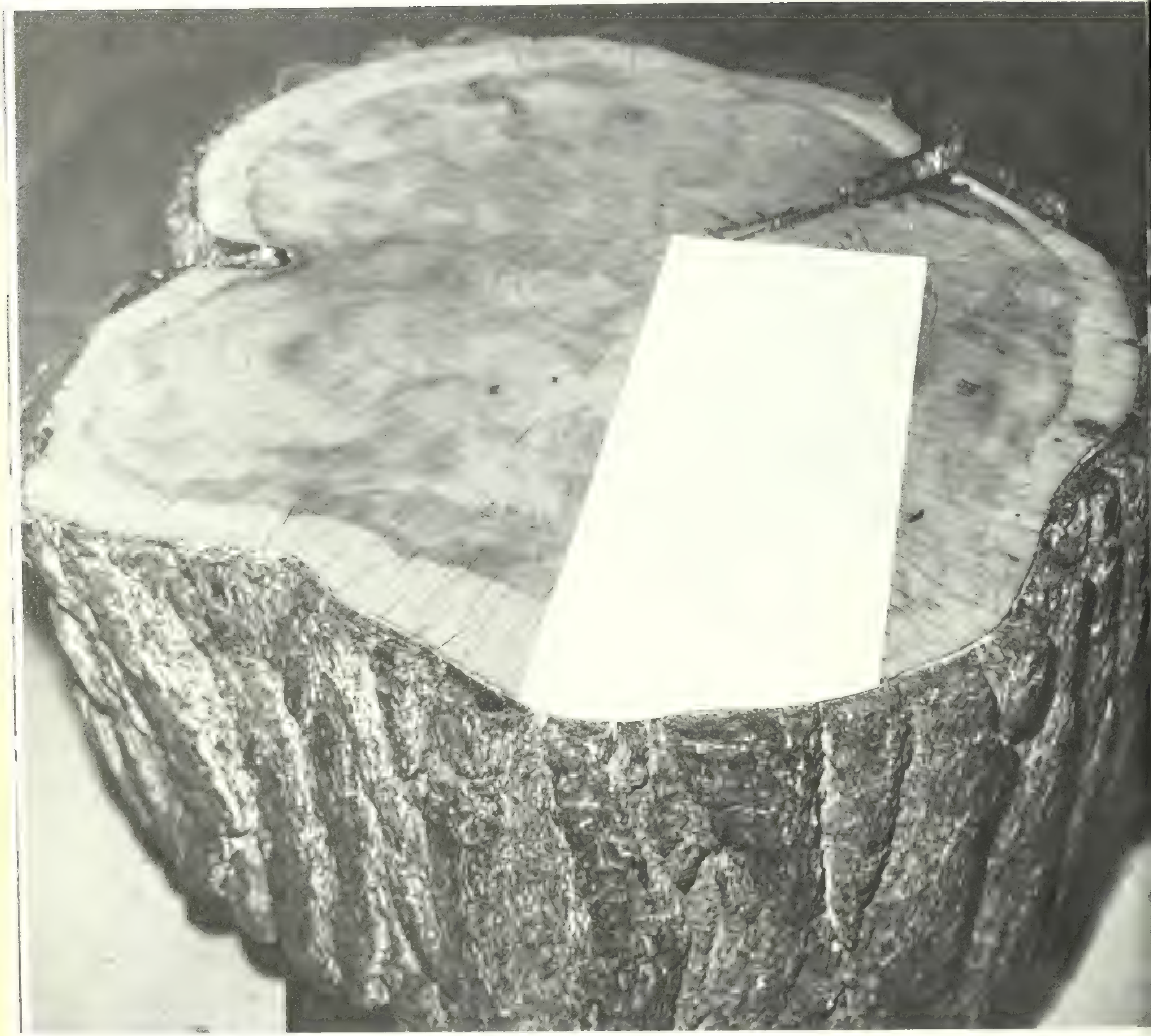
Range of viewing time, in minutes
1.0 to 16.1

Figure 6.—Diorama window overlooking Blue Mountain Lake.

Average time required to listen to the entire message	Average time visitors took to view the exhibits	Average percentage of required listening time that visitors used
Minutes	*Minutes*	*Percent*
2.1	1.3	64

Range of viewing time, in minutes
0.1 to 4.5

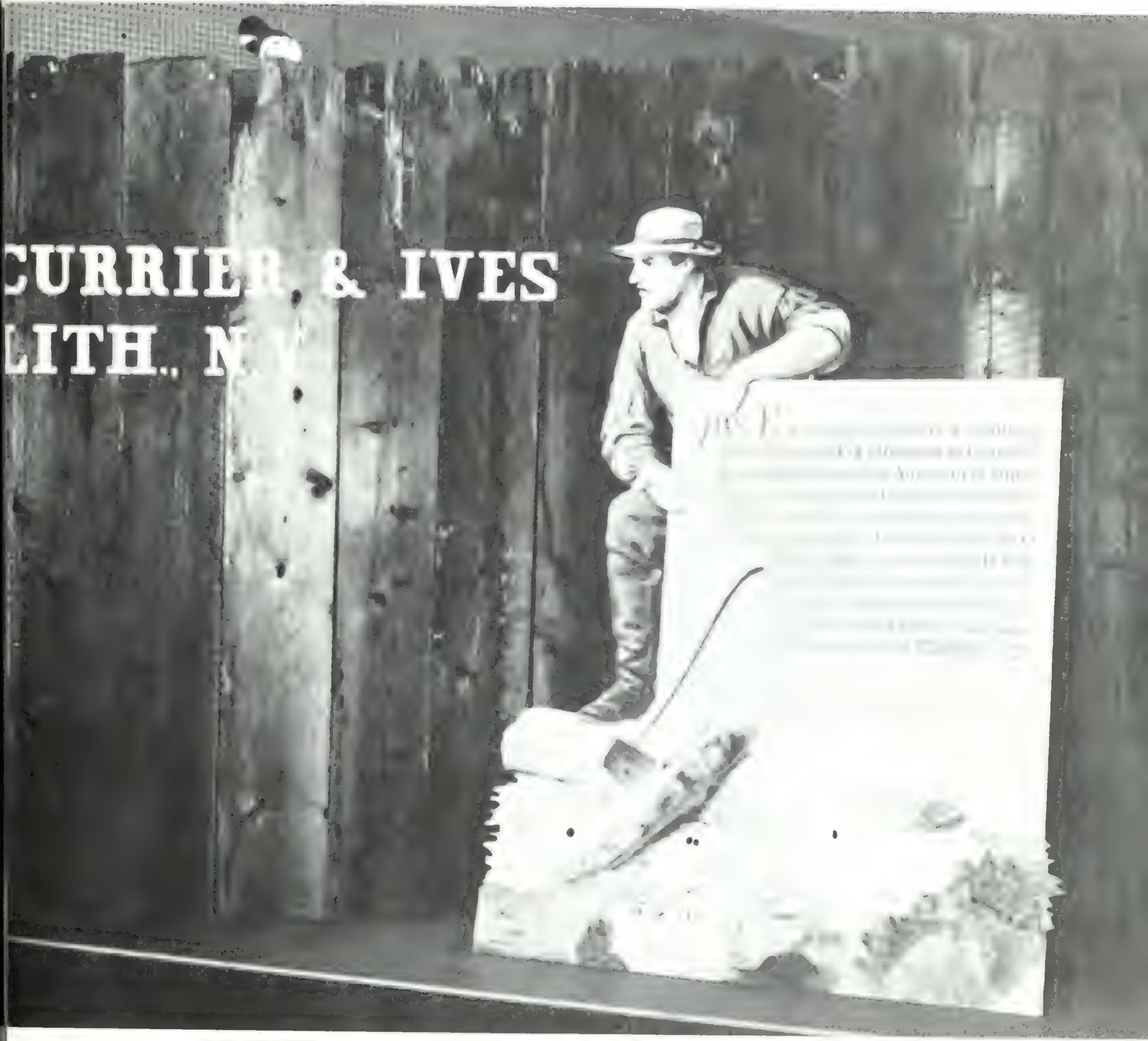
Figure 7.—White pine log section.



Average time required to read the entire message	Average time visitors took to view the exhibit		Average percentage of required reading time that visitors used	
	August	October	August	October
Minutes	*Minutes*	*Minutes*	*Percent*	*Percent*
2.3	1.0	0.8	43	35

Range of viewing times, in minutes	
August	*October*
0.2 to 3.3	0.1 to 1.3

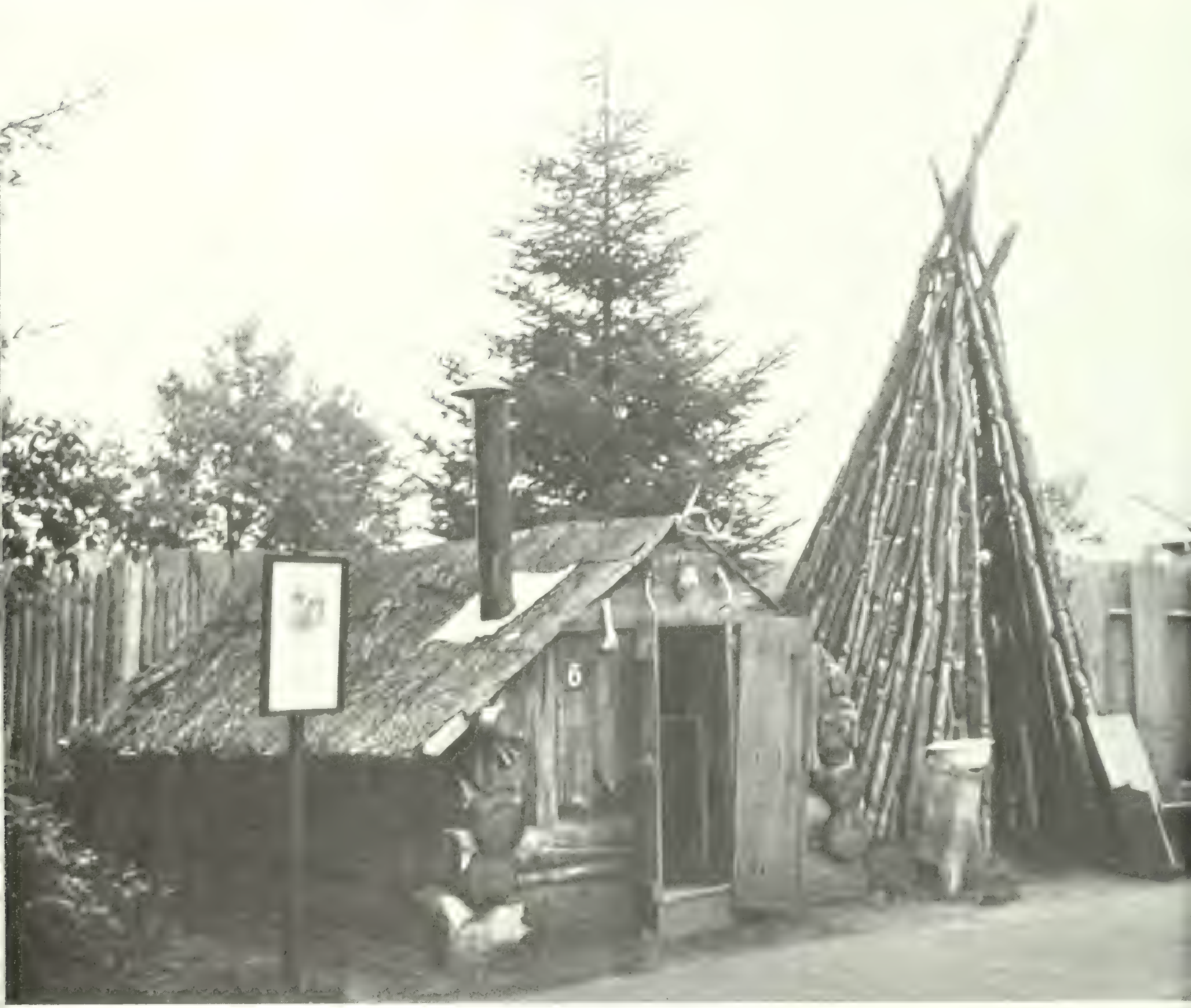
Figure 8.—Introduction to 42 Currier and Ives prints.



Average time required to read the entire message presented at all paintings	Average time visitors took to view all paintings	Average percentage of required reading time that visitors used
Minutes 6.3	*Minutes* 2.1	*Percent* 33

Range of viewing time, in minutes
0.3 to 5.6

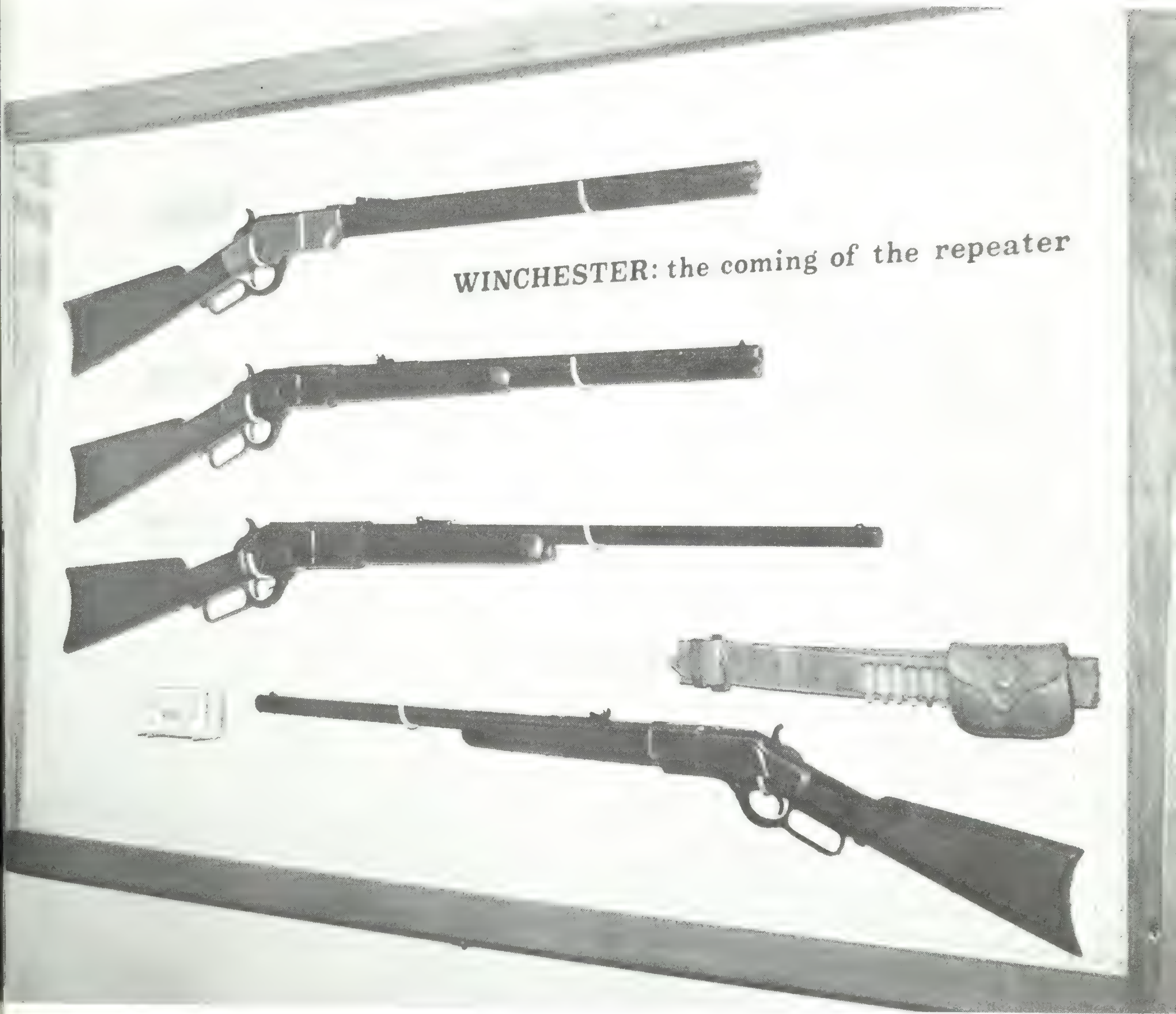
Figure 9.—Adirondack hermit's cabin and firewood-tepee.



Average time required to read the entire message	Average time visitors took to view the exhibit		Average percentage of required reading time that visitors used	
	August	October	August	October
Minutes	*Minutes*	*Minutes*	*Percent*	*Percent*
3.3	1.9	1.3	58	39

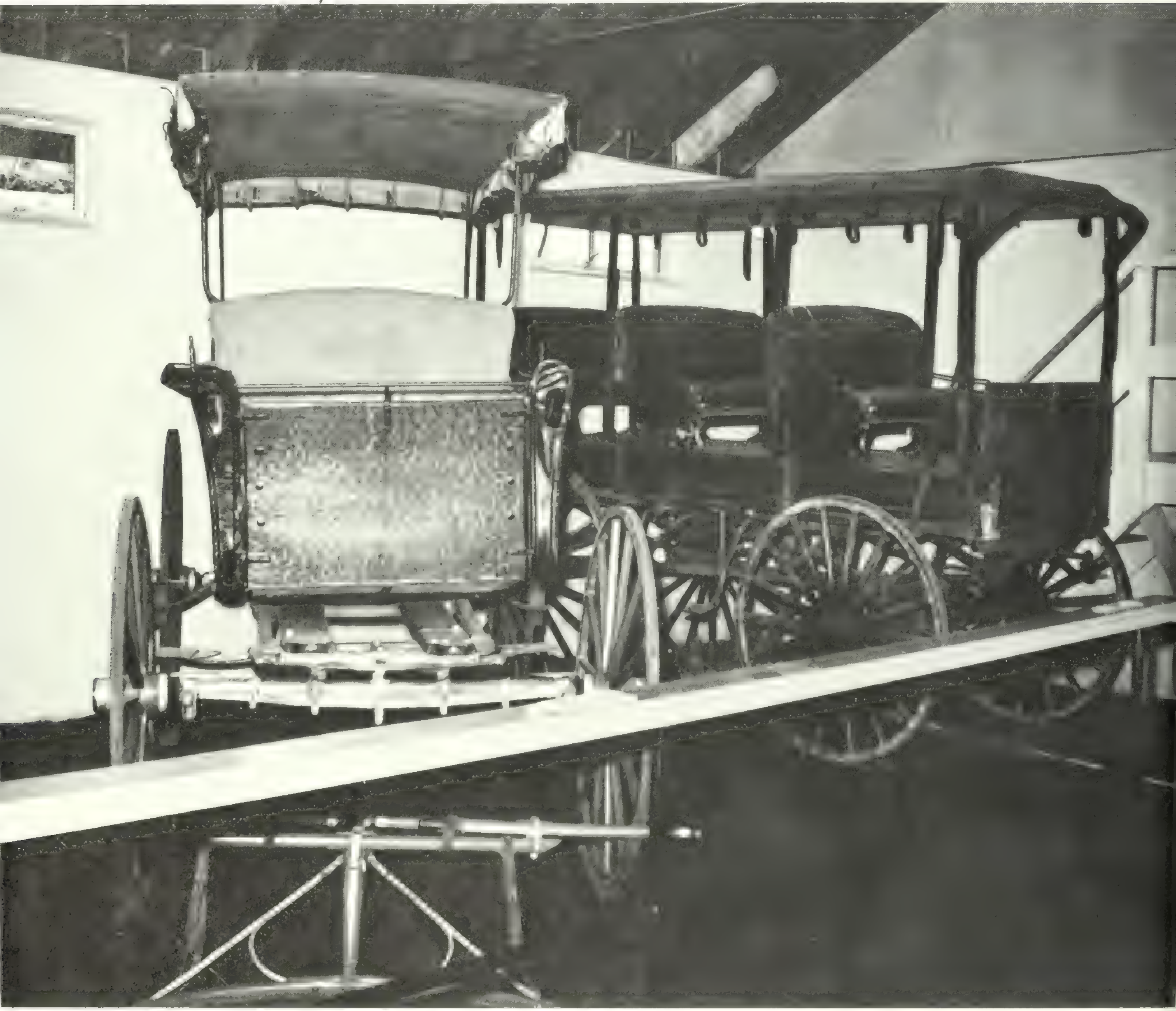
Range of viewing times, in minutes	
August	*October*
0.5 to 4.1	0.3 to 2.1

Figure 10.—A typcial part of the gun exhibit showing hunting rifles used in the Adirondacks.



Average time required to read the entire message	Average time visitors took to view the exhibit	Average percentage of required viewing time that visitors used
Minutes	*Minutes*	*Percent*
15.5	2.5	16
	Range of viewing time, in minutes	
	0.2 to 7.3	

Figure 11.—Part of the exhibit showing vehicles used during the early history of the Adirondacks.

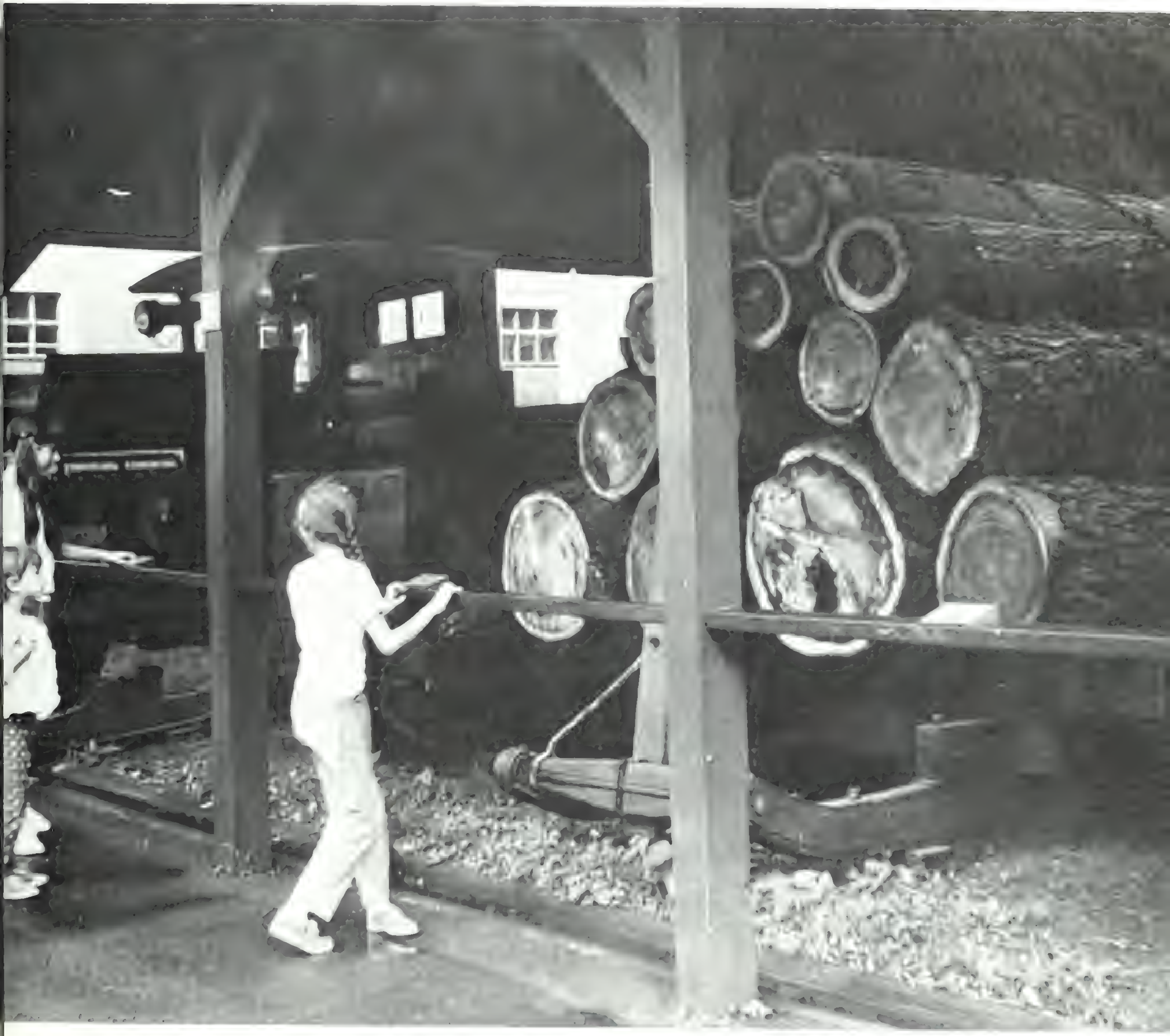


Average time required to read the entire message	Average time visitors took to view the exhibit		Average percentage of required viewing time that visitors used	
	August	October	August	October
Minutes 6.1	*Minutes* 3.9	*Minutes* 2.2	*Percent* 64	*Percent* 36

Range of viewing times, in minutes

August	*October*
0.3 to 6.0	0.2 to 7.1

Figure 12.—Part of the logging and road-maintenance vehicle exhibit.



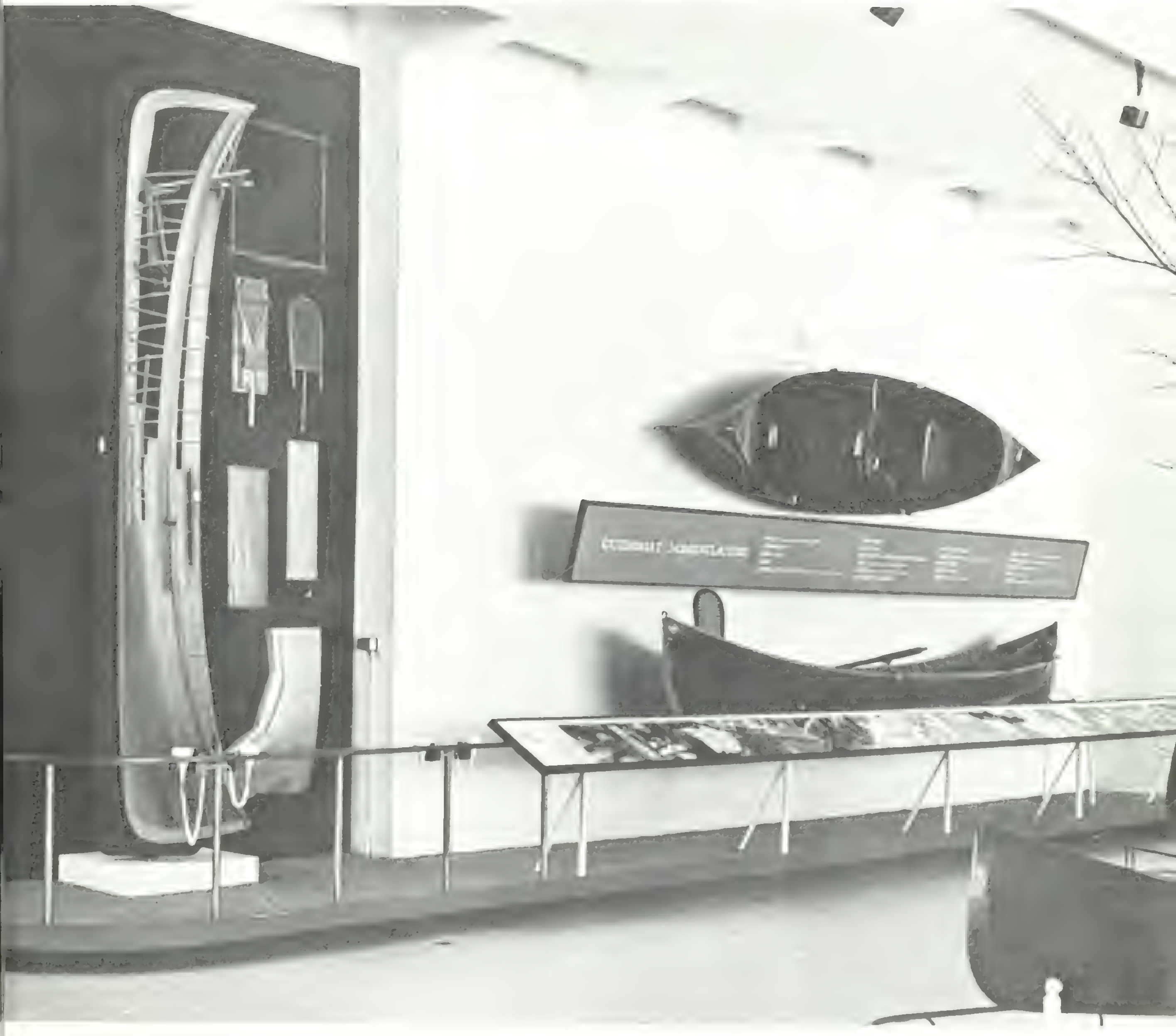
Average time required to read the entire message	Average time visitors took to view the exhibit	Average percentage of required viewing time that visitors used
Minutes 7.0	*Minutes* 2.7	*Percent* 39
	Range of viewing time, in minutes 0.4 to 5.4	

Figure 13.—An example of the many black and white photographs used in the photo belt to describe man's relationship to the Adirondacks.

Average time required to read the entire message	Average time visitors took to view the exhibit	Average percentage of required viewing time that visitors used
Minutes 28.0	*Minutes* 10.1	*Percent* 36

Range of viewing time, in minutes
0.1 to 25.0

Figure 14.—Part of the boat exhibit.



Average time required to read and listen to the entire message	Average time visitors took to view the exhibit		Average percentage of required viewing time that visitors used	
	August	October	August	October
Minutes	*Minutes*	*Minutes*	*Percent*	*Percent*
28.5	6.8	9.7	23	34

Range of viewing times, in minutes	
August	*October*
0.5 to 7.4	1.5 to 13.0

DISCUSSION

Variation Among Exhibits

Realism in an exhibit seems to affect visitor interest. Three exhibits that elicited 58 to 64 percent of total required reading or listening time were: the diorama vista-window (fig. 6), the vehicle building (fig. 11), and the hermit's camp (fig. 9).

Actual Versus Required Observation Time

Exhibits with messages requiring 2 to 4.9 minutes of viewer attention were actually viewed 1.3 minutes—or 45 percent of the total time required to read or hear the entire message. Exhibits with messages requiring 5 to 28 minutes of viewer attention were viewed for shorter times in relation to a message's total required reading or listening time. For example, only 27 percent of the total required reading or listening time was taken by visitors at exhibits that required 15 or more minutes (table 1)).

However, differences between the required viewing time and average observed viewing time at an exhibit are not necessarily a realistic index of that exhibit's drawing power. Rather than its printed message, an exhibit's variability, contrast, and uniqueness in comparison to other exhibits in a museum may be a more effective measure of that exhibit's drawing power and of its lasting effect on the viewer.

Undoubtedly, the average number of minutes that visitors spent at an exhibit were not devoted entirely to reading or listening to the exhibit's message. And some viewers listen to or read a message much faster than others. Therefore, the average time spent by visitors to comprehend an exhibit's entire message may have been even less than the reported average of 16 to 64 percent of required observation time reported here.

Results of this study showed variations in visitor viewing behavior at different types of exhibits. In this respect, the results may be useful to I & E planners.

However, the question whether the length of most messages should be reduced or increased cannot be inferred from our results — even though average observed viewing time per exhibit was always less than the average time required to read or listen to the entire message. The answer to that question requires a more detailed study that would find out how much information visitors retained.

Table 1.—Summary of behavior patterns at the 14 exhibits

Average time required to read or listen to the entire message	Exhibits in this category[1]	Average observed viewing time	Percentage of required reading or listening time actually used by visitors
Minutes	*No.*	*Minutes*	*Percent*
2.0 to 4.9	8	1.3	45
5.0 to 9.9	6	2.5	42
10.0 to 14.9	1	4.1	37
15.0 to 28.0	4	7.3	27

[1] Viewing times at any one exhibit during August and October were considered separately when the two months differed significantly.

Shiner, James William, and Elwood L. Shafer, Jr.
1975. **How long do people look at and listen to forest-oriented exhibits?** NE. For. Exp. Stn., Upper Darby, Pa.
16 p., illus. (USDA For. Serv. Res. Pap. NE-325)

The time that visitors spent looking at and listening to exhibits at the Adirondack Museum in New York was compared with the time actually required for reading exhibit material and listening to taped messages. Time spent ranged from 15 to 64 percent of time actually required.

945.24

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Silicone Antitranspirant Increases Susceptibility of Eastern White Pine to the White-Pine Weevil

NOV 5

by Ronald C. Wilkinson

USDA FOREST SERVICE RESEARCH PAPER NE-326
1975

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F. BRYAN CLARK, STATION DIRECTOR

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MANUSCRIPT RECEIVED FOR PUBLICATION 15 JANUARY 1975

Silicone Antitranspirant Increases Susceptibility of Eastern White Pine to the White-Pine Weevil

by Ronald C. Wilkinson

Abstract

Spraying 16-year-old eastern white pine (*Pinus strobus* L.) growing in a geographic seed-source test plantation with 10-percent silicone antitranspirant emulsion effectively increased internal water balance during the growing season when compared to control trees of the same seed sources that received no treatment. Extreme silicone toxicity was observed. Apical shoot elongation of treated trees averaged 37 percent of that of controls. Needle elongation of treated trees was also restricted. All of the treated trees were attacked by the white-pine weevil (*Pissodes strobi* Peck.), and leader mortality due to attack occurred in 90 percent of the trees. Only 51 percent of the control trees were attacked, and only 26 percent leader mortality occurred. High leader mortality in treated trees may have been due to increased egg production by female weevils in the moisture-favorable environment. The high numbers of treated trees attacked suggests that the antitranspirant may have initiated release of some unknown attractants of the host or directly or indirectly stimulated release of aggregating pheromone by the weevil.

Key words: eastern white pine; white-pine weevil; insect resistance; silicone antitranspirant; internal water balance

Introduction

RESISTANCE of some conifers to attack by insects is related to characteristics of oleoresin in the trees. High oleoresin exudation pressure and resin flow have been postulated as defense mechanisms against the white-pine weevil (*Pissodes strobi* Peck.), but this hypothesis has never been tested.

The first evidence of white-pine weevil attack is the appearance of droplets of resin exuding from holes made by adult weevils feeding on the growth of the preceding year. If the weevil attack is light, many of the developing larvae will be smothered by resin, and the terminal shoot will survive. The resistance of *Pinus peuce* Grisebach to the white-pine weevil has been attributed to the copious resin flow of this species (*Fowler 1957*; *Fowler and Heimburger 1958*). Occasionally a similar reaction will occur in eastern white pine (*Pinus strobus* L.).

Evidence suggests that oleoresin exudation pressure within individual trees is strongly inherently controlled (*Bordeau and Shopmeyer 1958*), but pressure and flow are influenced by many environmental factors; and they are particularly modified by internal tree water balance (*Mason 1971*).

The objective of this study was to determine whether increasing the internal water balance of eastern white pine by use of a silicone antitranspirant, and hence increasing oleoresin exudation pressure, has any bearing on increased resistance to the white-pine weevil.

Materials and Methods

I studied eastern white pine growing in a geographic seed-source test planted in 1960 on the Massabesic Experimental Forest in Alfred, Maine. The plantation contains 24 randomized blocks of 27 seed sources from throughout the species' range. Each seed source is represented in each block by a one-tree plot with a spacing of 10 × 10 feet. The individual trees were 16 years old when tested in the spring of 1974.

The plantation was not protected from insects after the 1967 growing season; thus it was ideal study material because of a large white-pine weevil population in the immediate area. This plantation was evaluated for phenotypic weevil resistance in 1970. Of 627 living trees in the plantation, only 22 trees had not been attacked by the weevil at least once during the 3-year period from 1968 through 1970.

Six of the 27 seed sources that were immediately above or below the plantation mean height—three above and three below—were used for this study. The six seed sources did not represent the extreme ranges of weevil susceptibility and resistance in the plantation; but three seed sources—Pennsylvania, Maryland, and New Brunswick, Canada—were moderately resistant: 26.4 to 37.5 percent of possible leader mortality due to weevil attack over the 3-year period 1968 to 1970. The three other seed sources—Minnesota, Quebec, and Ontario, Canada—were highly susceptible: 50.7 to 53.6 percent of possible leader mortality over the same period. Mean weevil attack success for the entire plantation of 27 seed sources was 45.3 percent.

Twelve of the 24 blocks were antitranspirant-treatment blocks, and the other 12 were unsprayed controls. The 12 treatment blocks were selected randomly by drawing 12 block numbers from an array of 24 numbers.

Therefore, there were ideally 6 × 12 = 72 individual trees sprayed and 6 × 12 = 72 individual trees of the same seed sources to serve as controls. Five of the trees were dead, so there were actually 69 sprayed trees and 70 control trees in the study.

Before spraying with antitranspirant, every tree in the plantation was pruned to one-half of its total height during the week of 7 April 1974. This was done to ease spraying operations and to reduce crown area to be covered by the antitranspirant.

On 10 April 1974, shortly before the onset of weevil activity in the area, the 69 treatment trees were sprayed with 10-percent concentration of Dow Corning XEF-4-3561 silicone antitranspirant. (Mention of specific products is for information only and is not an endorsement by the Department of Agriculture or the Forest Service.)

The trees were sprayed with a garden sprayer. The entire crown, except for the current-year leader, was carefully covered to surface saturation by direct spraying so that adjacent trees were not contaminated.

The single application was predicted to effectively reduce transpiration until 15 July 1974, at which time leader mortality due to weevil attack would be visible. At that time, treatment and control trees were evaluated for leader mortality, weevil feeding, and weevil resistance.

Shortly after these field evaluations were made, the two most recent main-stem annual growth whorls of each tree—treatment and control—were severed and brought into the laboratory for closer observation and confirmation of weevil damage. At the same time, measurements of current-year shoot growth were made on two randomly selected lateral branches from the uppermost whorl of each tree. The growth characteristics measured were: branch length, basal branch diameter, and the length of the longest needle from the first five-needle bundle on each branch. Differences in growth characteristics between treatment and control trees were tested by split-plot analysis of variance.

Water-potential measurements (for determining internal tree water balance) were also made on a small random sample of treatment and control trees by using a pressure bomb at two different times during the growing season (table 1). The first measurement was made on 20 May 1974, about 1 month after spraying; and the second was made on 8 July 1974, after apical growth was nearly complete. Measurements were made by C. A. Federer, principal meteorologist, Northeastern Forest Experiment Station, Durham, New Hampshire.

Table 1.—Mean midday water-potential measurements of randomly selected trees sprayed with silicone antitranspirant and control trees

Treatment	20 May 1974		8 July 1974	
	bars	No.	bars	No.
Antitranspirant	−4.58**	(8)[a]	−8.20**	(6)
Control	−11.00	(7)	−11.66	(6)

**Means within dates are significantly different at the .01 level.

[a] Number of trees sampled.

Results and Discussion

Spraying 16-year-old white pine with silicone antitranspirant increased the internal water balance of the trees. The effect was maintained during the entire period of white-pine weevil activity from initial feeding through oviposition, larval development, and adult emergence.

The silicone treatment produced two other effects that were totally unexpected. Most important, the susceptibility of eastern white pine to white-pine weevil attack and resulting leader mortality was greatly increased (table 2). In addition, current-year apical branch growth and needle expansion were significantly reduced (table 3), and the treatment ultimately led to the death of a number of trees.

Susceptibility to Weevil Attack

The increased susceptibility of eastern white pine to white-pine weevil attack as a result of silicone antitranspirant treatment is difficult to explain and has no precedent. Of the 67 sprayed trees examined in July, 60 of them or 90 percent had suffered leader mortality (table 2). The other seven trees were also attacked by the weevil; but they either resisted attack (larval development but no leader mortality), or feeding occurred without oviposition.

Table 2.—Number of trees attacked by weevils in silicone antitranspirant treatment group and control group

Category	Antitranspirant group	Control group
Total Trees	67[a]	70
Weevil Attack:		
Leader mortality	60	18
Weevil feeding	4	10
Resisted attack	3	8
Total	67	36
Trees not attacked	0	34

[a] Two trees sprayed with the silicone antitranspirant died before examination for weevil damage on 15 July 1974.

In contrast, of the 70 control trees, only 18 trees or 26 percent exhibited leader mortality: an equal number resisted attack or showed evidence of feeding activity only. Typical success of weevil attack leading to leader mortality ranges from 50 to 60 percent for the most susceptible seed sources.

The low number of control trees attacked is indicative of below-normal weevil activity; this particular plantation consistently has about 75 percent of the trees attacked yearly. Moreover, one seed source that has been highly susceptible in the past accounted for 25 percent of the weevil attacks and 39 percent of the leader mortality on control trees. Among the treatment trees, weevil attack and leader mortality were uniformly distributed among the six seed sources studied.

The greater weevil activity on sprayed trees suggests that some attractive mechanism may be involved. I feel that the evidence is overwhelming. Almost twice as many sprayed trees as control trees showed evidence of weevil attack. In addition, one particular tree that was treated with antitranspirant had 13 different branches weeviled, and all of these branches succumbed to attack.

Typically, only the leader or a single dominant lateral branch is attacked. In this study, the mean number of branches attacked per tree was 1.4 for control trees and 2.9 for trees treated with antitranspirant. No control tree

Table 3.—Means for current-year shoot growth (1974) of trees sprayed with silicone antitranspirant and control trees, in cm

Geographic seed source	Branch length[a]		Branch diameter[a]		Needle length[a]	
	Treatment	Control	Treatment	Control	Treatment	Control
Maryland	21.8	51.9	0.49	0.75	5.7	7.3
Pennsylvania	20.9	50.1	.45	.76	6.0	7.0
Minnesota	20.4	47.2	.51	.80	6.5	8.1
New Brunswick	19.3	56.6	.54	.94	6.6	8.0
Quebec	17.6	54.1	.46	.90	6.7	8.5
Ontario	21.1	61.0	.49	.97	5.4	6.9
All sources	20.3	53.5***	0.49	0.85***	6.1	7.8***

[a] Although there were small but significant seed-source differences for branch length, branch diameter, and small but significant interactions for branch length and branch diameter, these effects were minute relative to the large effects due to the antitranspirant treatment.

***Differences between overall treatment and control means are significant at the .001 level. Significance test based on split-plot analysis of variance.

had more than two branches attacked, and only 30 sprayed trees had two or fewer branches attacked. These differences were not attributable to branch size beause there were no significant differences in 1-year-old leader lengths or leader diameters between sprayed and control trees.

ODell (*1972*) found a positive correlation between stem moisture available to the adult weevil and the number of eggs laid during any particular feeding period. In laboratory tests, weevils placed on white pine branches that had absorbed water for 24 hours laid significantly more eggs than those maintained on branches without additional water.

Unfortunately, in this preliminary study, I was unable to make measurements of oleoresin exudation pressure. Assuming that some amount of oleoresin pressure increase did occur as a result of increasing internal water balance, the inhibitory effect of increased resin flow on larval development may have been compensated for by increased numbers of eggs laid. In that case, increased moisture content of the leader could account for some increased susceptibility to leader mortality. The evidence for some attractive mechanism also implies that more females may have been present, and thus more oviposition might occur as a result.

Increased moisture content could account for the high leader-mortality rate of attacked treatment trees. However, it may not account for the fact that 100 percent of the sprayed trees were attacked, while only 51 percent of the control trees were attacked.

The silicone emulsion, itself, may have acted as a weevil attractant. I have no evidence to support or refute this possibility. I suggest, however, that any attractant properties present were probably due to some metabolic change induced in the host trees by the antitranspirant; or the attracting mechanism might involve a male pheromone released by another stimulus such as high moisture content or higher concentrations of certain biochemicals (*ODell, personal communication*).

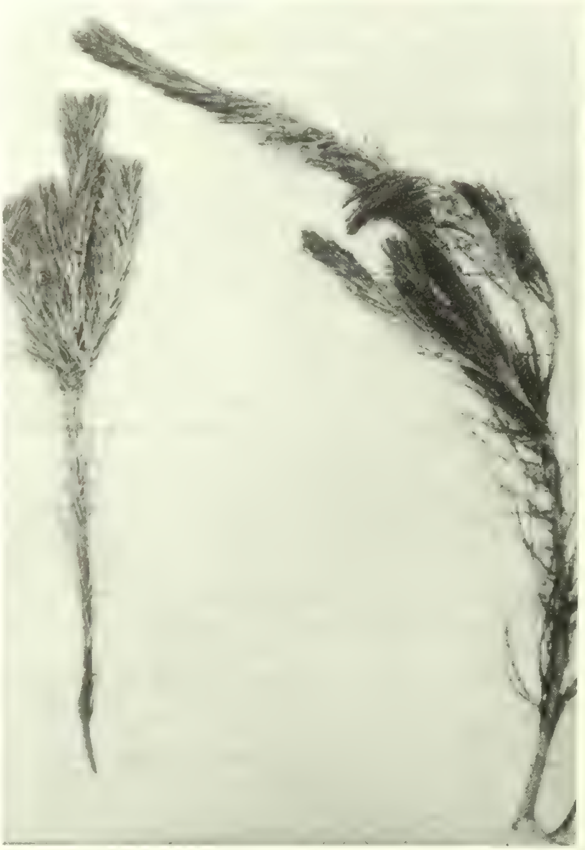
In a previous study (1972), I found that the white-pine weeevil may be attracted by high concentrations of two monoterpenes, mycrene and limonene, found in eastern white pine oleoresin. Perhaps the antitranspirant somehow altered the metabolism of some endogenous chemical or in some way influenced its release into the atmosphere where it could influence weevil behavior.

Silicone Toxicity

The sprayed trees exhibited all the symptoms of phytotoxicity found in a study by Lee and Kozlowski (*1974*): inhibition of needle expansion, decrease in chlorophyll content, leaf browning and spotting, and death of plants. Although chlorophyll content was not measured, a pronounced yellowing of the sprayed 1-year-old needles was easily observed within a few days after treatment.

The reduction in current-year shoot growth was particularly striking (fig. 1). Moreover, by

Figure 1.—Comparative current-year shoot growth (1974) of two trees of the same seed source. Left, sprayed with silicone antitranspirant; right, control.



15 July 1974, when weevil damage was evaluated, two of the sprayed white pines had died; and another 15 sprayed trees died by September 1974.

Toxicity was more pronounced in the plant material used in this study than in the study by Lee and Kozlowski (*1974*). They reported only slight damage on seedlings treated with 10-percent silicone; and even with 20-percent silicone emulsion, all eight white pines used in their study were alive after 3 months. This suggests that toxicity could vary greatly within species.

The difference in the efficiency of the silicones as antitranspirants and their toxicity within species could be due to genotypic variation in response. However, unique weather conditions at the time of application, the seasonal timing of the application, pruning before treatment, or a number of other environmental factors cannot be discounted as possible causes. Differences in stomatal size as well as other differences in needle structure may also be involved (*Lee and Koslowski 1974*).

Heinlein and Haigh (*1971*) reported that 10-percent silicone emulsions were not toxic to numerous species of conifers and broadleaved plants. However, Lee and Kozlowski (*1974*) found that the elongation of new (current-year) needles of *Pinus resinosa* and *Pinus strobus* was significantly retarded by 10- and 20-percent silicone, which they suggested was due to inhibited photosynthesis in old needles as a result of the treatment. This could be the basis for the growth reduction and mortality of the trees in my study.

Conclusion

Whatever mechanism is responsible for the increased susceptibility of white pine to the white-pine weevil after treatment with silicone antitranspirant, the results of this study, which were totally unexpected and, in fact, directly opposed to those originally hypothesized, could have valuable future implications in developing a white pine that will be resistant to white-pine weevil attack.

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by David R. Houston

Soil Fumigation to Control Spread of *Fomes annosus*: Results of Field Trials

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MANUSCRIPT RECEIVED FOR PUBLICATION 10 MARCH 1975

ABSTRACT

A field trial was run to test the hypothesis that a band of roots killed by soil fumigation with methyl bromide would be unsuitable for invasion by *F. annosus* and would block the underground spread of the fungus from diseased trees to healthy trees. Infection centers in red pine plantations from New York to Rhode Island were delineated on the basis of symptoms and fruiting bodies, and were treated. Development of disease was observed in 11 centers for 4 years. Excavation and isolation from roots of trees and stumps adjacent to the fumigation line showed that the fungus had crossed the zone in only two centers, was prevented from crossing in many places in at least four centers, and was already outside the zone at the time of the treatment in six centers. The primary reason for failures appeared to be the inadequacy of the methods used to delineate the infection centers.

Additional key words: Red pine, *Pinus resinosa*, root rot, infection centers.

INTRODUCTION

PRELIMINARY STUDIES on the use of soil fumigation to prevent underground spread of *Fomes annosus* (Fr.) Cke. from diseased to healthy red pine trees (*Pinus resinosa* Ait.) were described in 1969 (*Houston and Eno 1969*). Results from these trials showed that methyl bromide, injected into the soil along a line adjacent to living red pine trees, killed all the roots in a continuous band from 5 to 7 feet (1.5 to 2.1 m) wide. These killed roots were soon colonized by soil fungi and apparently were rendered unsuitable for invasion by *F. annosus.*

These results, along with others that revealed that *F. annosus* was eliminated by fumigation from most dead infected roots, prompted establishment of a field trial in 1967-68 to test the use of soil fumigation in preventing the underground spread of *F. annosus* in a number of active infection centers.

This report is a summary of results from this field trial after 4 years.

MATERIALS AND METHODS

Fifteen infection centers in red pine plantations located in New York (7), New Hampshire (3), Rhode Island (2), and Connecticut (3) were treated in October or November (12 in 1967, 3 in 1968). Four centers in New York were abandoned later. Two of these were inadvertently harvested and two were in a plantation found to be heavily colonized throughout by *F. annosus.*

All infection centers contained trees dying from *F. annosus* attack. The centers were separated from each other by at least 10 rows of apparently healthy trees, and the perimeter of each center was less than 4 chains (80.5 m) except for one center that had a perimeter of 17 chains (342 m).

The extent of the infection centers and the locations of the fumigation lines were determined by the presence of fruiting bodies of *F. annosus* on trees and stumps. The fumigation line was established at least one healthy tree beyond the outermost tree or stump bearing fruit bodies. The positions of the stumps and trees in each plot were mapped, and their disease conditions were recorded (presence of fruiting bodies; and for trees, the color of the crown—green, yellow, brown).

Methyl bromide, at the rate of 1 pound (0.454 kg) per every 8 (1967) or 10 (1968) linear feet (2.4, 3.0 m), was dispensed into 20-inch-deep (50.8 cm) holes punched at 1-foot (0.3 m) intervals along the fumigation line as described earlier (*Houston and Eno 1969*). (Dow Chemical Co., Midland, Mich., provided material. Mention of a particular product should not be taken as an endorsement by the Forest Service or the U. S. Department of Agriculture.)

The effectiveness of the fumigant in killing roots, the progress of disease development, and the extent of fungus movement across the fumigation zone were measured in each plot. Six months after treatment, the roots in 2-foot-wide (0.6 m) trenches dug at right angles across the fumigation line were examined to determine if roots had been killed. Each center was examined annually for 4 years (1971 or 1972) to follow disease development (presence of fruit bodies and crown symptoms) inside and outside the plot, and to determine if break-over of infection had occurred.

At the close of the study in 1971 or 1972, all places where *F. annosus* had appeared on trees or stumps outside the fumigation zone, and many places where disease spread appeared to have been arrested by the treatment, were excavated. The root systems were mapped, and root sections were removed for isolation of the pathogen. Root sections were washed under tap water and aseptically split longitudinally. Wood chips were plated onto a 2-percent malt agar medium and were examined after 7 days for the presence of *F. annosus*.

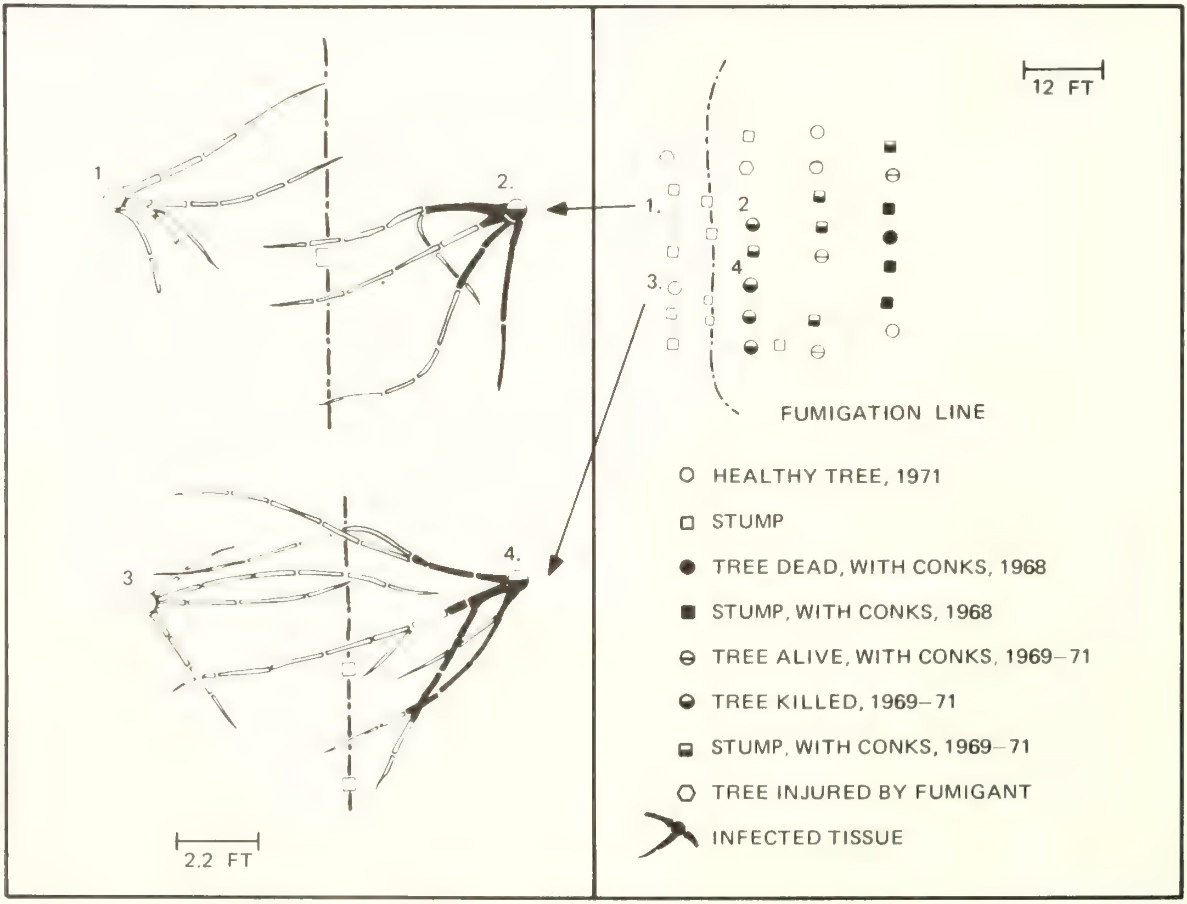
RESULTS

Six months after treatment, all red pine roots had been killed back to distances ranging from 2.5 feet (0.8 m) to 6 feet (1.8 m) on either side of the fumigation line. However, the roots of both white pine (*P. strobus* L.) and Norway spruce (*Picea abies* [L.] Karst.) in several plantations where these species were mixed with red pines seemed to be unaffected by the fumigant.

Growth of new roots into the fumigation zone 2 years after treatment was determined in 2-foot-wide (0.6 m) trenches cut across the zone in several centers. In four trenches, small new roots, 4 to 6 inches (10.2 to 15.2 cm) below the soil surface, extended into the fumigation zone, sometimes as far as the injection line (3 to 4 feet, 0.9 to 1.2 m). In another six trenches, no roots had grown into the zone.

Some trees adjacent to the injection line were injured above ground by the fumigant. Marked cambial injury occurred on trees closer than 4 feet (1.2 m) from the line. On some trees the cambium of the entire side

Figure 1.—Disease development in a portion of a large infection center from 1968 to 1971 (right) and the results of isolation from roots excavated in 1972 (left). The fumigant treatment effectively blocked the spread of *F. annosus* across the fumigation zone.


1
2.
3
4.
2.2 FT
12 FT
1.
2
3.
4
FUMIGATION LINE
○ HEALTHY TREE, 1971
□ STUMP
● TREE DEAD, WITH CONKS, 1968
■ STUMP, WITH CONKS, 1968
⊖ TREE ALIVE, WITH CONKS, 1969–71
◒ TREE KILLED, 1969–71
▣ STUMP, WITH CONKS, 1969–71
○ TREE INJURED BY FUMIGANT
INFECTED TISSUE

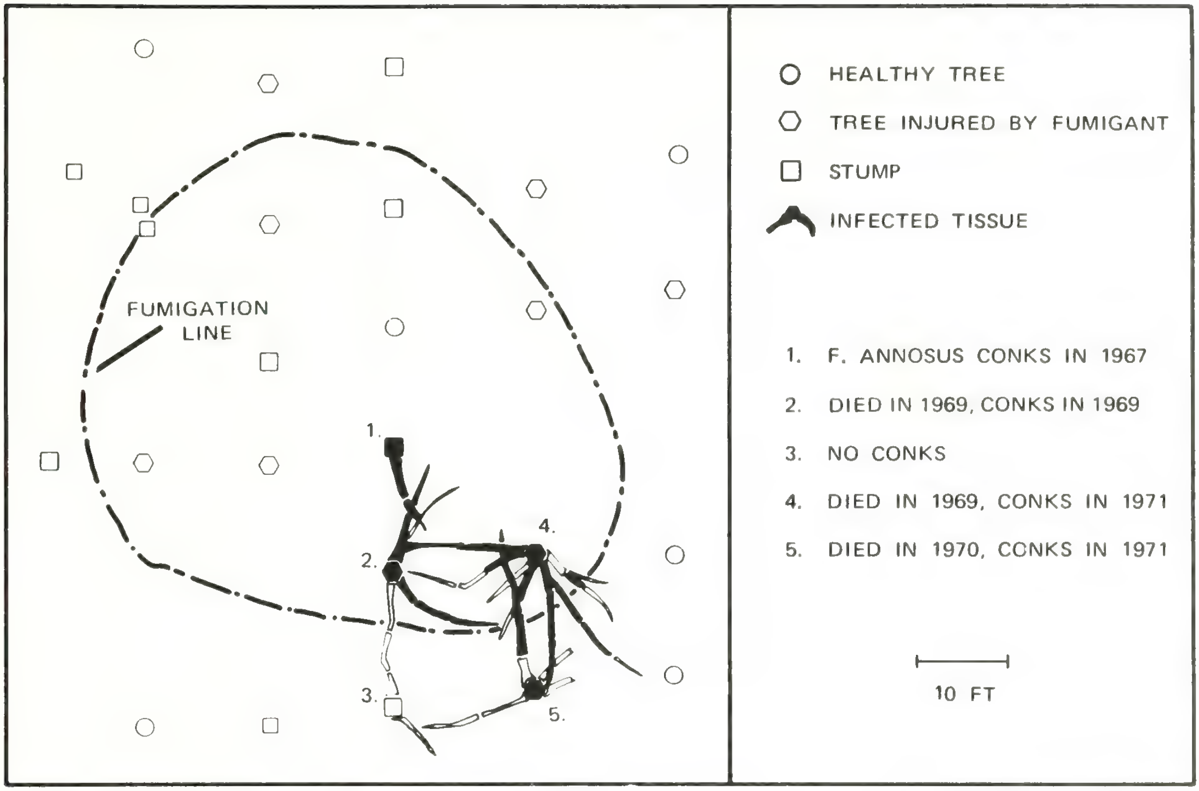

FUMIGATION LINE
1.
2.
3.
4.
5.
○ HEALTHY TREE
⬡ TREE INJURED BY FUMIGANT
☐ STUMP
INFECTED TISSUE
1. F. ANNOSUS CONKS IN 1967
2. DIED IN 1969, CONKS IN 1969
3. NO CONKS
4. DIED IN 1969, CONKS IN 1971
5. DIED IN 1970, CONKS IN 1971
10 FT

Figure 2.—Disease development in an infection center from 1967 to 1971 and the results of isolations from roots excavated in 1971. *F. annosus* crossed over the fumigation zone on fumigant-killed roots of a tree that was infected at the time of treatment.

facing the injection line was killed to 10 feet (3.0 m) or more above ground.

The dosage rate was reduced from 1 pound of methyl bromide per 8 linear feet (2.4 m) of line in 1967, to 1 pound per 10 linear feet (3.0 m) in 1968 to avoid this injury. But even at the lowered rate, cambial injury occurred on many trees. Indeed, in several instances, trees as far as 6 to 7 feet (1.8 to 2.1 m) from the line were affected. During the course of the study, a number of these fumigant-injured trees died after they were colonized by one or more species of bark beetles and borers.

The treatment appeared to have successfully blocked the outward spread of the fungus in one to several places in at least four plots. (fig. 1). The fungus was isolated from roots up to the point where they had been killed earlier by the fumigant. In one case, the fumigation treatment had blocked the passage into the plot of *F. annosus* from an undetected infected tree outside the plot. In two plots, infections outside the fumigation zone appeared to have originated when the fungus crossed the zone on fumigant-killed roots. In figure 2, the roots of tree 4 that were killed by fumigation soon became colonized by *F. annosus*. Crown symptoms in 1968 indicated that tree 4 was infected at the time of treatment.

In six plots, old stumps and trees (outside the fumigation zone) were found that had been infected previously. Fruiting bodies usually did not develop on old infected stumps until mid-way through the study.

DISCUSSION AND CONCLUSIONS

In this study there were many instances where the fumigant-killed root barrier seemed to inhibit spread of *F. annosus.* Most of these were cases in which saprophytic fungi had had the opportunity to thoroughly colonize the killed roots before they were attacked by *F. annosus.* If the fumigant-killed roots could be inoculated with an aggressive fungus antagonistic to *F. annosus*—such as *Peniphora gigantea* (Fr.) Massee (*Rishbeth 1961*)—the success rate of the treatment might be markedly enhanced.

Of the 11 centers followed throughout the study, only two developed outside infections that clearly appeared to have crossed the fumigation zone. In both cases, the pattern of disease development (revealed by tree symptoms and conk development) suggests that the apparently healthy tree next to the fumigant line was already infected at the time of treatment. It is likely that killing of roots on the side opposite an encroaching infection may have helped speed the pathogen across the freshly killed tissue ahead of colonization by saprophytic fungi.

The absence of fruiting bodies and of symptoms obviously is not reliable evidence of freedom from infection. In many cases, old stumps created in thinnings 5 to 8 years before treatment bore fruiting bodies one to several years after treatment—clear evidence that they had been infected many years earlier.

A possible aid in detecting infected, nonsymptomatic, and nonfruiting trees is the Shigometer (Northeast Electronics Corporation, Concord, New Hampshire). Shigo and Berry *(in press)* reported the successful use of this instrument to discriminate between healthy and infected red pine trees. The use of this instrument to detect infected living trees would probably have reduced the instances where break-over occurred and those cases where failure occurred because previously infected trees were missed outside the fumigation zone.

Although roots of white pine and Norway spruce were not affected by the fumigant, and both species were infected with *F. annosus,* no instances of break-over could be attributed to their presence. However, the possibility that roots of these species could serve as bridges across a fumigation zone should be considered in any control attempt.

The above-ground bole damage and tree mortality caused by fumigation and subsequent beetle attack could have been reduced considerably had trees adjacent to the fumigation line been removed at the time of treatment, or if the fumigation line had been run along rows of stumps of trees removed at the time of treatment. If such procedures were followed, the stump surfaces should be treated *(Hodges 1974)* to preclude their infection by airborne spores of *F. annosus.*

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Rishbeth, J.
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4 p., illus. (USDA For. Serv. Res. Pap. NE-327)

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414.27 : 443.3 - - 172.8 : 416.3

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Low-temperature Forced-air Drying of Appalachian Hardwoods

by

Donald G. Cuppett and E. Paul Craft

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MANUSCRIPT RECEIVED FOR PUBLICATION 31 MARCH 1975

Low-temperature Forced-air Drying of Appalachian Hardwoods

ABSTRACT

Low-temperature forced-air drying involves drying green lumber in heated buildings with forced-air circulation and partial control of temperature and humidity conditions. The lumber is dried to about 20 percent moisture content at dry-bulb temperatures of 70° to 110°F and with air velocities of 300 to 600 feet per minute. Equipment, methods, and procedures for commercial application of low-temperature drying in the Appalachian hardwood region are described, including dryer design and construction, drying schedules and drying times for commercially important Appalachian species, and detailed instructions for operating the dryer and using the schedules. In test runs, these drying times were recorded:

Species	Thickness	Final moisture content	Drying time
		percent	*days*
Red oak	4/4	20	19-23
Red oak	8/4	25	57-62
Hard maple	4/4	20	8-10
Hard maple	5/4	20	12-14
Hickory	4/4	20	16-18
Hickory	5/4	20	22-24

The recommended drying schedules and procedures are designed so the dryer can be operated with little or no venting. Humidity conditions are controlled by manipulating the dry-bulb temperature and utilizing the moisture released in drying for humidification.

IN 1967 WE BEGAN RESEARCH to evaluate low-temperature forced-air drying of Appalachian hardwoods. In our initial study, we compared drying times, costs, and degrade losses for low-temperature drying vs. air drying of 4/4 Appalachian red oak *(2)*. We have now developed low-temperature drying schedules and procedures for other thicknesses of oak, and for several thicknesses of other important Appalachian woods. This report includes a discussion of dryer design, drying schedules, and dryer operating procedures for commercial use in the Appalachian region.

Low-temperature drying was developed to alleviate some of the problems involved in air-drying lumber in open yards. The low-temperature method involves drying the lumber in totally enclosed heated buildings having internal forced-air circulation systems. Green lumber is dried to about 20 percent moisture content at temperatures of 70° to 110°F and with air velocities of 300 to 600 feet per minute.

Low-temperature drying is much faster than air-drying. For most species and thicknesses of Appalachian hardwoods, low-temperature drying times are about one-third of the average air-drying times. Therefore low-temperature drying requires only one-third of the lumber inventory necessary for air-drying an equivalent volume of lumber.

The low-temperature method also permits better control of drying degrade than air-drying does. In the Appalachian region, degrade losses in commercial air-drying operations average about 5 percent of lumber value. In commercial low-temperature drying, degrade losses can be limited to 1 or 2 percent of lumber value.

LOW-TEMPERATURE DRYER DESIGN

Two general types of low-temperature drying facilities are in commercial use: low-temperature kilns and low-temperature dryers. Low-temperature kilns are equipped with automatic controls for the heating, humidification, and vent systems *(1)*. Low-temperature dryers have thermostats for temperature control and either manual controls or humidistats for the humidification and vent systems. Similar building construction, fan systems, and other design features are used for both types of drying equipment. However, the drying schedules, procedures, and related information in this report apply only to low-temperature dryer operation.

Dryer Size and Capacity

The capacity of commercial units varies from 12 to more than 100 thousand board feet. But most of the dryers used for oak and similar hardwoods are in the 25-to 50-thousand board-foot range. The dryer used in our research has a capacity of about 25 thousand board feet of 4/4 lumber, or about 28 thousand board feet of 8/4 lumber. The building is 28 feet wide by 36 feet long and holds four kiln-car loads of box-piled lumber

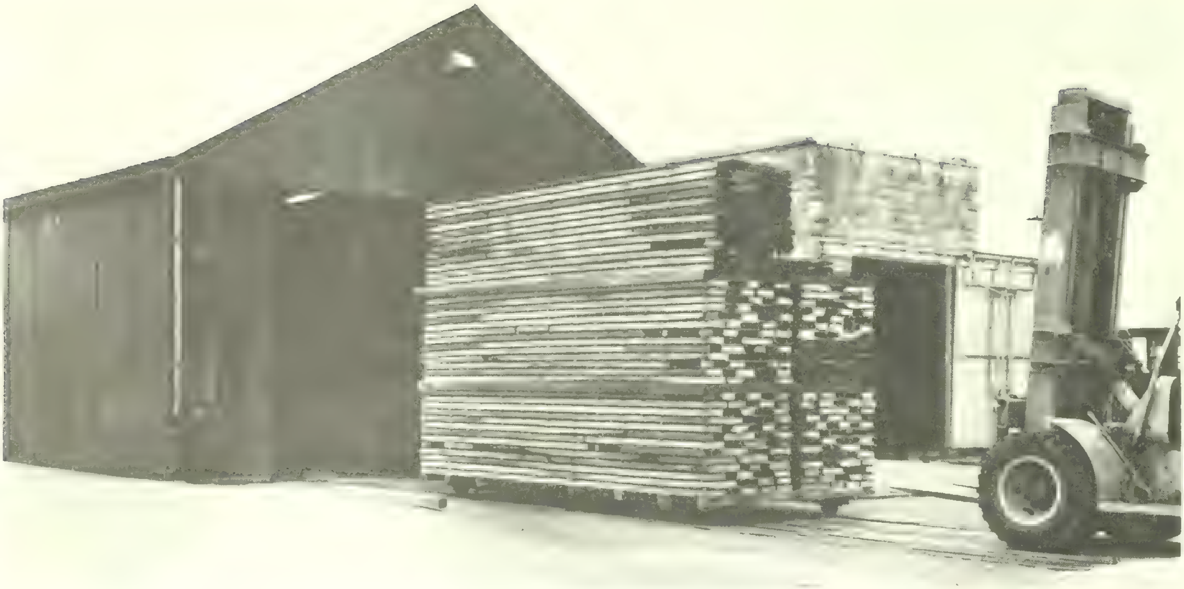


Figure 1.—The commercial-scale experimental low-temperature dryer used in developing drying schedules for Appalachian hardwoods, and a partial kiln-truck load of 8/4 red oak lumber. The dryer is of pole-type frame construction, sided with exterior plywood.

on two tracks. Each load is 8 feet wide, 16 feet long, and about 11 feet high (fig. 1).

For dryers having larger capacities, a four-track dryer is preferable to a longer two-track dryer. The former provides greater capacity per square foot of building size, and greater capacity per number of fans and per horsepower required to operate the fan system.

Building Construction

The drying building must house the lumber, fans, and heating system; and it must have adequate plenum-space to facilitate air flow. Aside from these general requirements, availability and cost of local building materials are the most important considerations in selecting type of building.

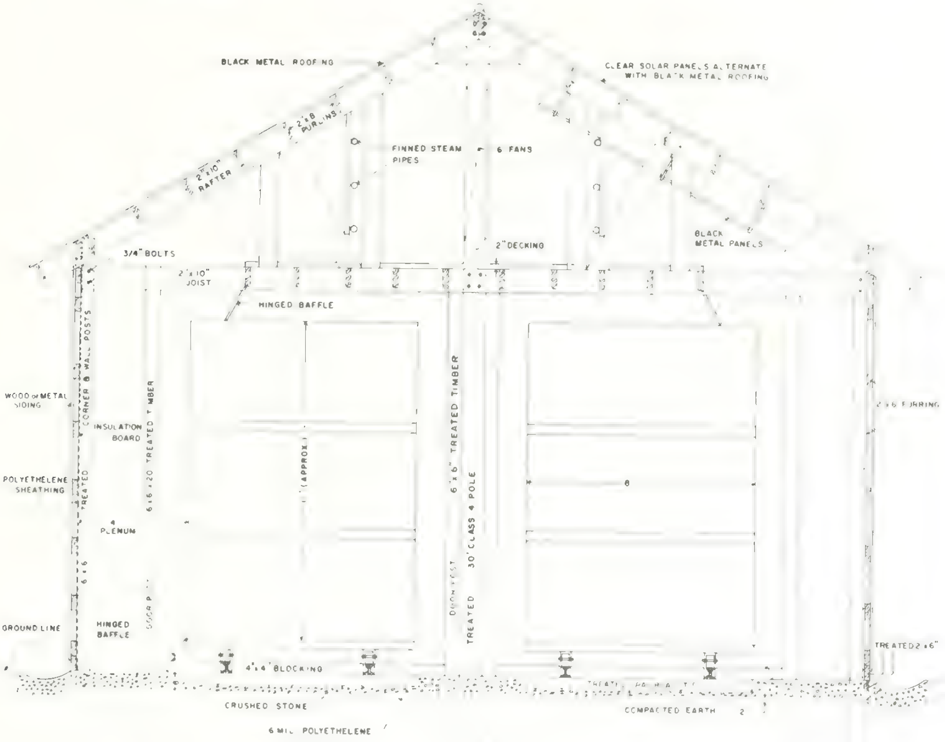
A variety of building types can be used. The most common are pole-type buildings clad with plywood, lumber, metal, or composition-board siding, and with metal or asphalt roll roofing (figs. 2, 3, and 4). Buildings having masonry-block or studded-wall construction can also be used. In some instances, existing buildings such as drying sheds have been converted successfully for use as low-temperature dryers.

For track-loaded dryers, floors can be earthen, crushed stone, asphalt, or concrete. Earthen and crushed stone floors should be underlain with a polyethylene vapor barrier (fig. 2). Dryers designed for forklift loading should have paved floors or runways. The pavement and base should be adequate for supporting the forklift during loading and unloading operations. See local state highway codes for pavement and base requirements.

The walls of dryers having lumber, plywood, or metal siding fastened to purlins or studs should have an inner wall of ½-inch asphalt-impregnated insulation board to provide an insulating air space. The inner wall should be underlain with a 6-mil polyethylene vapor barrier (fig. 2). The interior surfaces of masonry block walls should be coated with a commercial kiln coating.

Roofing can be insulated by fastening insulation board or 10-mil polyethylene film underneath the rafters or roof purlins to

Figure 2.—Front elevation of typical dryer with fans located overhead.



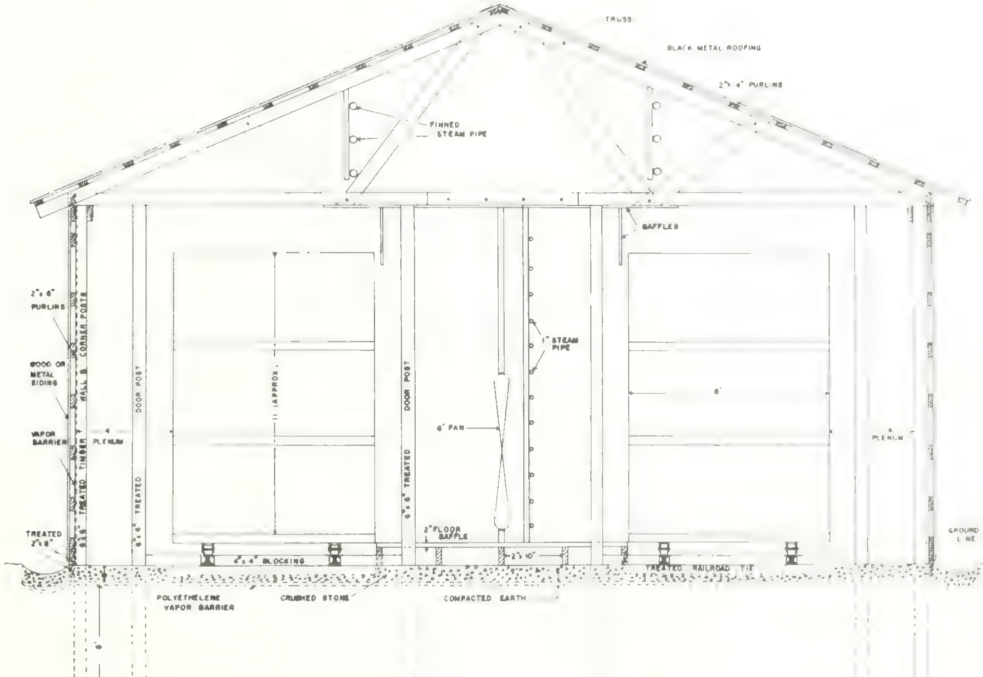


Figure 3.—Front elevation of typical dryer designed with fans located on floor baffle.

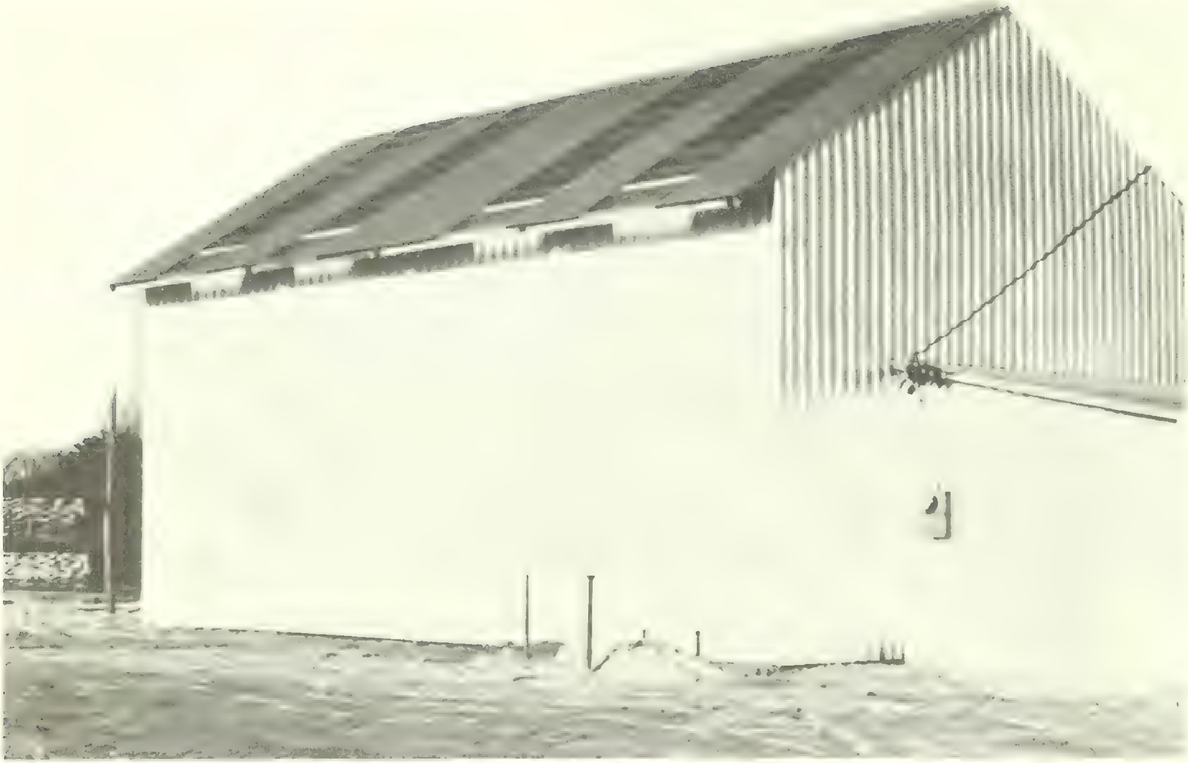


Figure 4.—Side view of a commercial low-temperature dryer. The building is of pole-type frame construction, sided and roofed with corrugated metal. The south slope of roof contains clear panels to absorb solar energy.

provide an air space. The polyethylene film should be stretched tight, stapled to the rafters, and secured by narrow wood strips.

Because of current high fuel costs and the need for fuel conservation, further insulation of dryer buildings is probably warranted. A recent analysis of our experimental dryer by a local heating engineer showed that the addition of 1½ inches of fiberglass or equivalent insulation to the walls, doors, and roof would result in sufficient fuel savings to repay the cost of insulation in about 2 years.

Doors can be constructed of 2-inch wood framing, sheathed on the outside with metal or exterior plywood and covered on the inside with ½-inch asphalt-impregnated insulation board. The insulation board should be underlain with a 6-mil polyethylene vapor barrier, and the air space in the door should be filled with fiberglass insulation. Doors can be either hinged or hung on a track system. The latter is preferable for dryers constructed for forklift loading, because of the large doors required. One advantage of the track-loaded dryer design is that fewer and smaller doors can be used; this results in fewer cracks at door joints and consequently less heat loss.

Heating Systems

Low-temperature dryers can be heated by steam, hot water, or direct forced-air systems. In some instances, dryers are heated entirely by surplus or exhaust steam. About 1 boiler-horsepower or equivalent per thousand board feet of dryer capacity is required to achieve the desired dry-bulb temperatures.

In addition, dryers can be designed to utilize solar heat for supplementing conventional heating systems. To aid in the absorption of solar energy, dryer roofs, exterior door surfaces, and exterior wall surfaces (except for masonry block walls) should be painted black. Dryers having metal roofs can be modified to absorb additional solar energy by alternating the metal roofing panels with translucent fiberglass panels on the southernmost side of the dryer (figs. 2 and 4). Energy transmitted through the fiberglass is collected on the black-painted aluminum panels located underneath and parallel to the fiberglass roof panels; air from the fans passes over both sides of the aluminum panels and distributes the heat throughout the dryer. If the dryer roof is ceiled to provide an insulating air space, the roof sections beneath the fiberglass panels should be ceiled with clear polyethylene film.

The dryer heating system must be arranged so that heat is distributed evenly along a line perpendicular to the direction of air flow, for the entire length of the building. In addition, the system should be designed so that the air will not pass through more than 16 feet of lumber without being reheated.

Fan System

Dryer fan systems should produce air velocities of 500 to 600 feet per minute through the lumber *(4, 6)*. Such air velocities are attained most economically by large-diameter multiblade fans run at low speeds. For example, to provide a given volume of air per minute, a 6-foot fan turning at 270 rpm will require only about 10 percent of the power needed for a 3-foot fan turning at 1,100 rpm *(3)*.

Loads should be baffled at floor, ceiling, and ends to force air through the lumber and prevent it bypassing around the load (figs. 2 and 3). Also, where 4 x 4s are used as package separators, the openings should be covered with narrow boards. To further facilitate air flow, the dryer should be designed to provide a minimum of 4 feet of clear space (plenum) between the outside walls and the adjacent loads and between the roof and ceiling baffles (fig. 2).

A typical overhead fan system for a 2-track dryer is shown in fig. 5. The four 6-foot fans, driven by two 7½ horsepower motors, provide a mean air velocity of about 500 feet per minute through a load containing 25 thousand board feet of 4/4 lumber. The load consists of 63 layers of box-piled lumber (random widths and lengths), with a total load length of 32 feet. For a 4-track dryer of 50 thousand board-foot capacity, the same number and size of fans, powered by two 10-horsepower motors, would produce similar air velocities *(1)*.

The fan system can also be located on a floor baffle about 1 foot above ground level (fig. 3). Where this arrangement is used, the building has to be about 6 feet wider than is needed for dryers with overhead fan systems. However, the roof trusses for dryers with overhead fan systems are heavier and more expensive than those used in dryers with floor-level fan systems. Thus, overall costs of dryers with the two types of fan systems are about equal.

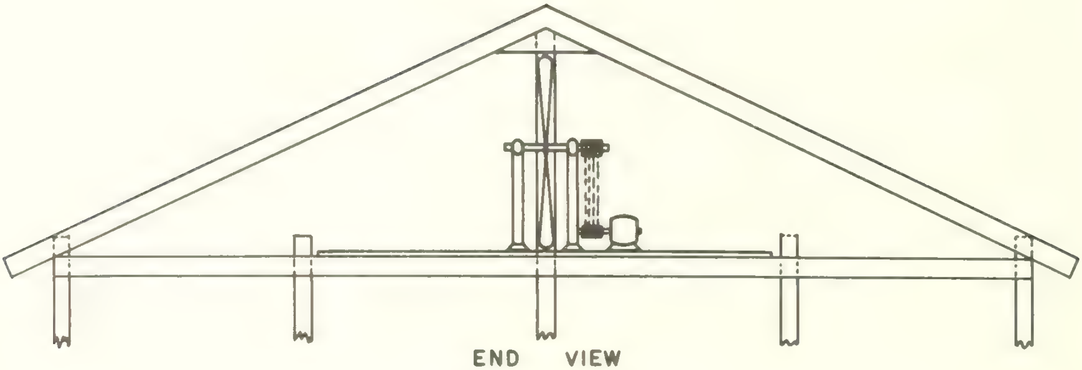
For dryers having total load widths exceeding 8 feet, fan motors should be provided with switch gear and time clocks to permit automatic reversal of air flow at intervals of 3 to 6 hours. Separate controls should be provided for each motor in the fan system; this will permit operation of only two fans when lower air velocities are desired for drying 6/4 and 8/4 oak, beech, and hickory (see schedule 4).

Low-temperature dryers can be provided with humidification systems and vents. But in most cases, neither is required for the drying schedules and procedures given in this report. Humidity conditions can be controlled adequately by manipulating the dry-bulb temperature and utilizing the moisture released in drying for humidification.

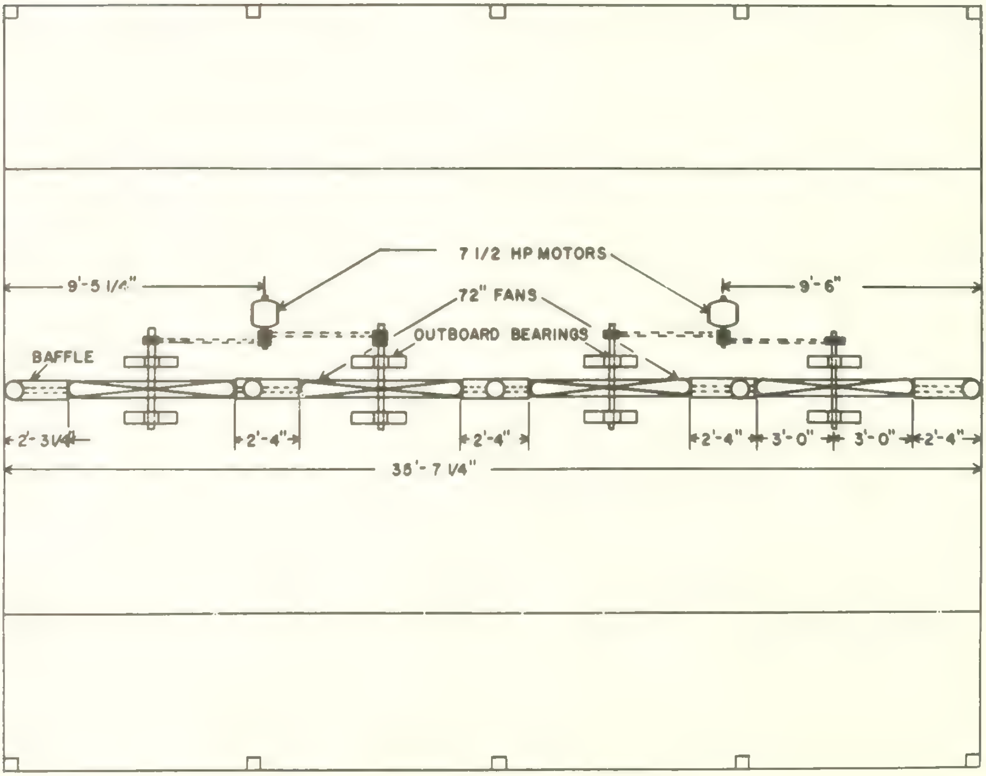
For most species and thicknesses of Appalachian hardwoods, cracks around the doors provide sufficient venting for efficient dryer operation. But in some locations, additional venting may be needed in the early stages of drying yellow-poplar, basswood, butternut, and buckeye. The additional venting can be obtained from a 12-inch-diameter louvered fan located in the gable at one end of the dryer (fig. 1). The fan can be controlled either manually or by a humidistat set to turn on the fan whenever the wet-bulb

FORCED-AIR DRYER

FAN SYSTEM



END VIEW



PLAN VIEW

Figure 5.—Overhead fan system used in the dryers illustrated in figures 2 and 4. The fan system can also be located on a floor baffle about 1 foot above ground level (fig. 3).

Table 1.—Low-temperature drying schedules for Appalachian hardwoods

Step No.	Moisture content	Dry-bulb temperature	Wet-bulb depression[a]
SCHEDULE 1			
1	Green to 40%	75° to 85°F	4°F
2	40 to 20%	95°F	No control
Air velocity 450-600 feet per minute; vents closed.			
SCHEDULE 2			
1	Green to 40%	70° to 80°F	3°F
2	40 to 25%	90°F	No control
Air velocity 500 to 600 feet per minute; vents closed.			
SCHEDULE 3			
1	Green to 45%	80° to 90°	7°F
2	45 to 20%	100°F	No control
Air velocity 450-600 feet per minute; vents closed.			
SCHEDULE 4			
1	Green to 40%	70° to 80°F	3°F
2	40 to 25%	90°F	No control
Air velocity 250-350 feet per minute; vents closed.			

[a] Step-1 wet-bulb depressions can normally be maintained only for the first day or two of drying.

depression is less than that listed in step 1 of the appropriate drying schedule (table 1).

Loading Method

Dryers can be designed for loading and unloading with either track or forklift. Choice of loading method depends mainly on the lumber-handling facilities and methods used by the firm. Total space required for the dryer and loading area is about the same for both loading methods. Forklift loading requires a level space about 30 feet wide in front of each entry; track loading requires a similar level area on each side of the tracks.

LOW-TEMPERATURE SCHEDULES

Schedules for drying rough-sawn Appalachian hardwoods are shown in table 1. Species and thicknesses that can be dried on each schedule are as follows:

Species	Schedule 1	Schedule 2	Schedule 3	Schedule 4
Red oak	4/4	5/4	—	6/4, 8/4
White oak	4/4	5/4	—	6/4, 8/4
Beech	4/4, 5/4	6/4	—	8/4
Hickory	4/4, 5/4	6/4	—	8/4
Hard maple	6/4	8/4	4/4, 5/4	—
Soft maple	6/4	8/4	4/4, 5/4	—
Cherry	6/4	8/4	4/4, 5/4	—
Birch	6/4	8/4	4/4, 5/4	—
Yellow-poplar	6/4, 8/4	—	4/4, 5/4	—
Basswood	8/4	—	4/4, 5/4, 6/4	—
Butternut	8/4	—	4/4, 5/4, 6/4	—
Buckeye	8/4	—	4/4, 5/4, 6/4	—
Ash	6/4	8/4	4/4, 5/4	—
Black walnut	5/4	6/4, 8/4	4/4	—

OPERATING PROCEDURES

The sample board (kiln-sample) system should be used for monitoring drying progress *(5, chapter VI)*. An equal number of samples should be selected from the slower drying stock (wide, thick, quarter-sawn boards) and the faster drying stock (narrow, thin, plain-sawn boards.) Use one sample per kiln-truckload or per 5,000 board feet of lumber.

Establishing the step 1 wet-bulb depression is the most important procedure in using the drying schedules. As the dryer warms up, the wet-bulb temperature rises with the dry-bulb temperature for a while, then begins to lag behind. This lag (wet-bulb depression) increases as the dry-bulb temperature increases. Using larger step-1 wet-bulb depressions then specified in the schedules can result in objectionable checking, particularly when drying oak, beech, and hickory.

During the warm-up phase of drying, dry-bulb and wet-bulb temperatures should be determined with a psychrometer (fig. 6). Temperature readings should be made at the air-inlet side of the load. After step-1 drying conditions are established, dry-bulb temperatures can be monitored with the thermometer attached to the dryer thermostat.

The following procedures should be followed for drying a charge of lumber (schedule 1 is used as an example):

1. After the dryer is loaded and baffles are in place, turn on the heat and fans, and set the dryer thermostat at 85°F (maximum step-1 dry-bulb temperature for schedule 1).
2. Determine the wet-bulb depression about once an hour, beginning when the dry-bulb temperature reaches 75°F (minimum step-1 dry-bulb temperature for schedule 1).
3. When a 4°F wet-bulb depression is obtained, reset the thermostat at the prevailing dry-bulb temperature; however, do not use a thermostat setting higher than 85° or lower than 75°F.

   Note: It is not necessary to maintain the initial wet-bulb depression throughout step 1. After a day or two of drying, the wet-bulb temperature will decrease slowly; but the change will not be fast enough to cause objectionable drying degrade.
4. During warm, sunny weather, solar heat will cause daytime dry-bulb temperatures to exceed thermostat settings by varying amounts (fig. 7). If during step 1 the dry-bulb temperature exceeds the thermostat setting by more than 5°F, lower the thermostat setting by 5°F and maintain the lower setting throughout step 1.
5. When the samples have dried to an average moisture content of 40 percent (step 2 beginning moisture content), reset the dryer thermostat at 95°F (step 2 dry-bulb temperature for schedule 1). Maintain this setting until the samples reach the desired final moisture content.

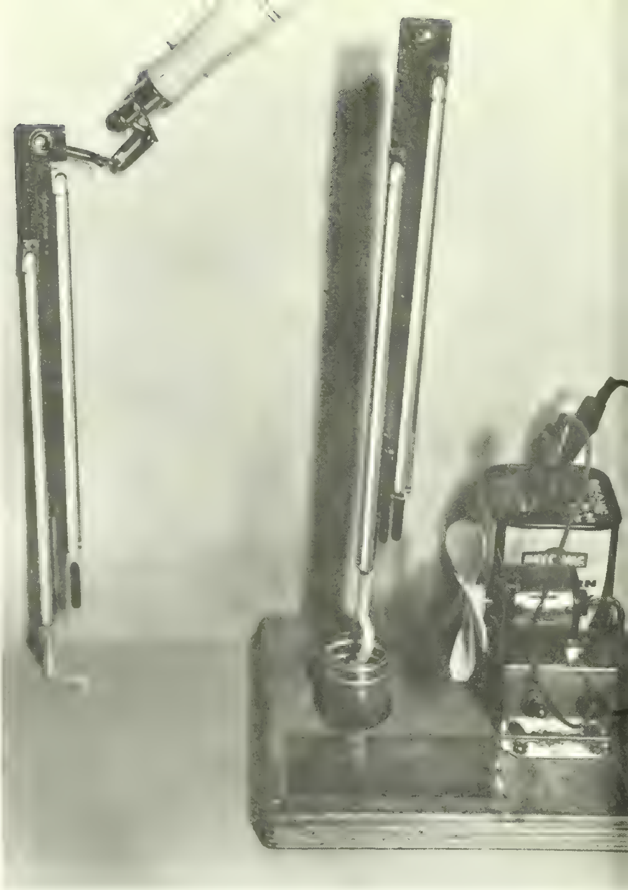


Figure 6.—Sling- and fan-type psychrometers. Either type can be used for determining wet-bulb depression during early stages of drying.

The amount of time required to dry green lumber to step 2 beginning moisture content

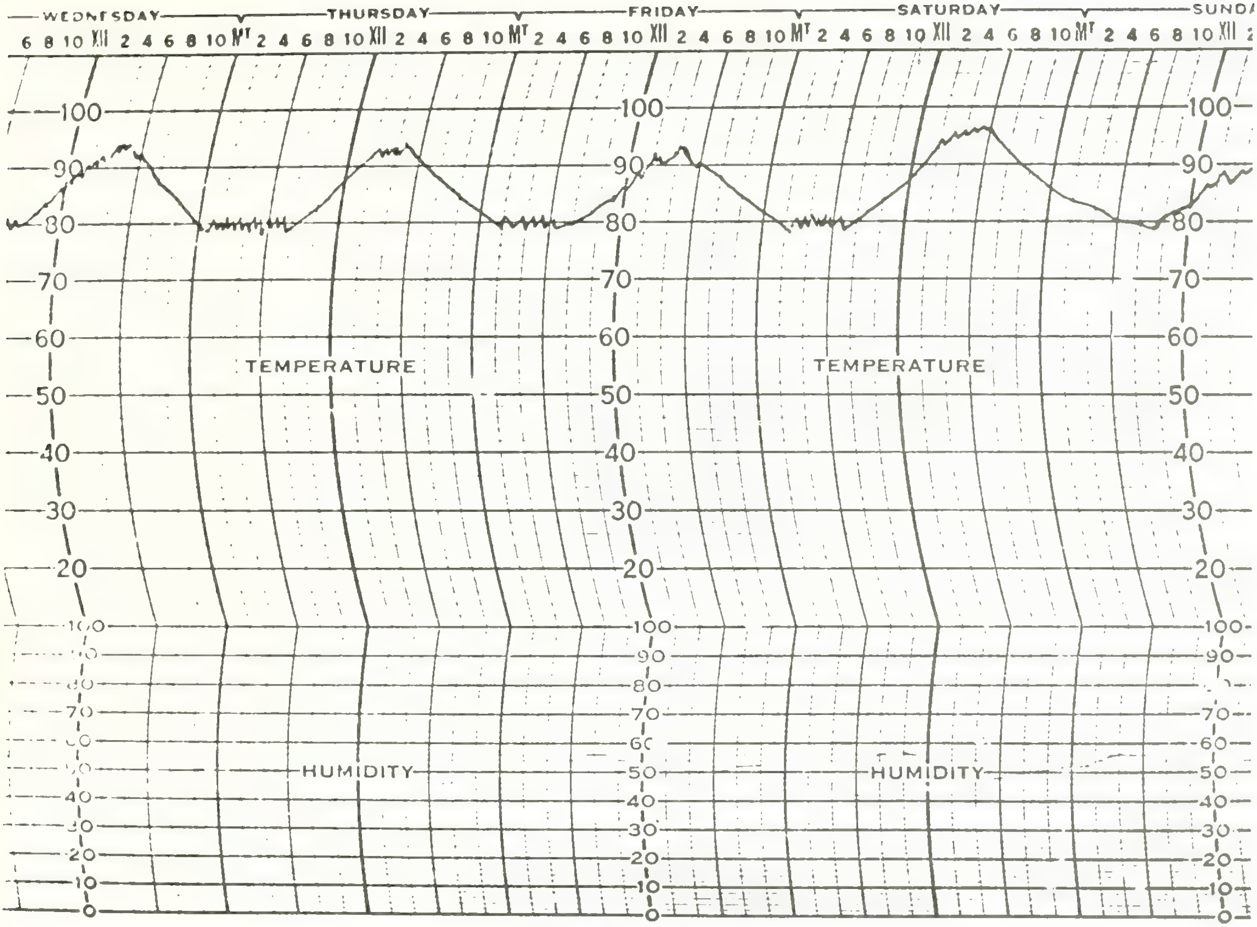


Figure 7.—Temperature chart made while drying a charge of lumber on schedule 1. Solar heat caused the dry-bulb temperature to exceed the 80°F thermostat setting about two-thirds of each 24-hour period.

varies considerably, even for a given species and thickness. The following are examples for several charges we have dried on the different schedules:

Thickness and species	Schedule No.	Drying time, green to step-2 beginning moisture content
		(days)
5/4 beech	1	3-5
4/4 red oak	1	6-9
4/4 hickory	1	3-5
5/4 hickory	1	4-6
5/4 red oak	2	15-18
8/4 red oak	4	29-38
5/4 soft maple	3	2-3
4/4 yellow-poplar	3	2-3
5/4 yellow-poplar	3	4-5

Special care should be taken when drying 6/4 oak and 8/4 oak, beech, and hickory. The green lumber should be end-coated, stickered, and placed in the dryer as soon as possible after sawing. Use only enough fans to provide 250 to 350 feet per minute air velocity through the lumber (see schedule 4). Even with these precautions, objectionable checking may take place in some charges of lumber. When this occurs, the fans should be operated only at night until the lumber dries to 40 percent average moisture content.

Table 2 shows the range of time required for drying several species and thicknesses of rough green lumber on schedules 1 through 4. Five-quarter and thicker red and white oaks should be dried to about 25 percent

Table 2.—Low-temperature drying times for green lumber

[Appalachian hardwoods]

Species	Thickness	Final average moisture content	Drying time
	Inch quarters	*Percent*	*Days*
Red oak	4/4	20	19-23
	5/4	25	30-35
	8/4	25	57-62
White oak	4/4	20	17-20
	5/4	25	28-32
	8/4	25	55-60
Beech	4/4	20	8-10
	5/4	20	10-12
Soft maple	4/4	20	6-7
	5/4	20	7-8
	5/4	12	11
Hard maple	4/4	20	8-10
	5/4	20	12-14
Hickory	4/4	20	16-18
	5/4	20	22-24

average moisture content. At lower moisture contents, the drying rates are too slow to justify the cost of dryer operation. The 4/4 red and white oaks, and 4/4 through 8/4 thicknesses of other Appalachian species, should normally be dried to 20 percent average moisture content. But for 4/4 and 5/4 soft maple, beech, yellow-poplar, basswood, buckeye, and butternut, satisfactory drying rates can be maintained to about 15 percent average moisture content.

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A guide for commercial application of low-temperature forced-air drying of Appalachian hardwood lumber, providing (1) descriptions of dryer design and construction, (2) drying schedules and estimated drying times for different thicknesses of commercially important species, and (3) detailed instructions for dryer operation.

OXFORD: [847.1 -- 087 + 847.2 -- 082] : 176.1
KEYWORDS: Drying, hardwoods, forced-air drying, predrying, drying equipment, procedures.

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Stump Sprout Growth and Quality of Several Appalachian Hardwood Species After Clearcutting

by G. W. Wendel

USDA FOREST SERVICE RESEARCH PAPER NE-329
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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
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MANUSCRIPT RECEIVED FOR PUBLICATION 9 DECEMBER 1974

Common and scientific names of species referred to in this study:

Cherry, black	*Prunus serotina* Ehrh.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, chestnut	*Quercus prinus* L.
Oak, northern red	*Quercus rubra* L.
Oak, white	*Quercus alba* L.
Yellow-poplar	*Liriodendron tulipifera* L.

Stump Sprout Growth and Quality of Several Appalachian Hardwood Species After Clearcutting

Abstract

Results of a 10-year study showed that stumps from 50- to 60-year-old red oak, black cherry, yellow-poplar, white oak, and chestnut oak trees sprouted vigorously. A high percentage of the dominant sprouts had good stem form, and many had excellent height and diameter growth. For all species, we found that the proportion of stumps sprouting, number of sprouts per stump, and dominant-sprout height were not correlated with parent-tree vigor or parent-tree dbh. In red oak, sprouting was not related to season of cutting or site quality.

INTRODUCTION

THE INCREASED USE of clearcutting in second-growth central Appalachian hardwood stands has indicated the need for more information about the growth and development of sprouts.

In general, the greatest objection to sprout stands is the high incidence of butt rot that often occurs. However, most investigators have concluded that butt rot in sprouts can be reduced by cutting low stumps so that sprouts originate close to the ground.

In 1963, we began to study the growth and development of red oak stump sprouts on excellent and fair sites in West Virginia. One-half of the study stumps were from trees cut during the growing season, and the other half were from trees cut during the dormant season. The growth and development of some black cherry, yellow-poplar, white oak, and chestnut oak sprouts were also observed; but these species were confined to one site and, with the exception of black cherry, to one season of cutting.

This paper is a report on sprout growth over a 10-year period and an evaluation of dominant-sprout quality after 11 years.

METHODS

The study was set up on two sites on the Fernow Experimental Forest near Parsons, West Virginia. Red oak, yellow-poplar, and black cherry were the major species on the excellent site (S.I. [site index] 80 for oak); and red oak, chestnut oak, white oak, and red maple were most common on the fair site (S.I. 60 for oak) *(Schnur 1937)*.

Both stands were even-aged, about 55 years old, and vigorous at the time of cutting (figs. 1 and 2). Two 1-acre plots were established on each site. One plot was cut in February 1963

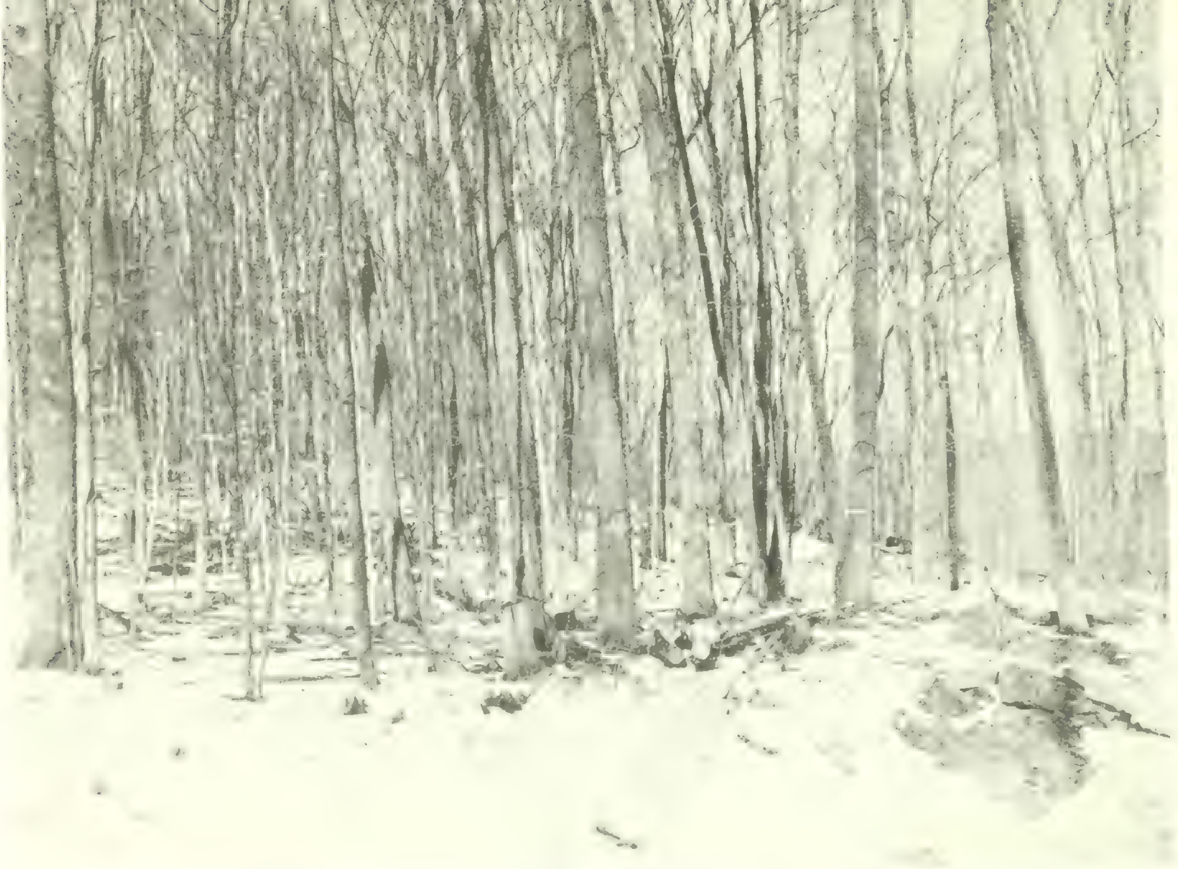


Figure 1.—Typical stand on the site index 80 area before cutting.

Figure 2.—Typical stand on the site index 60 area before cutting.

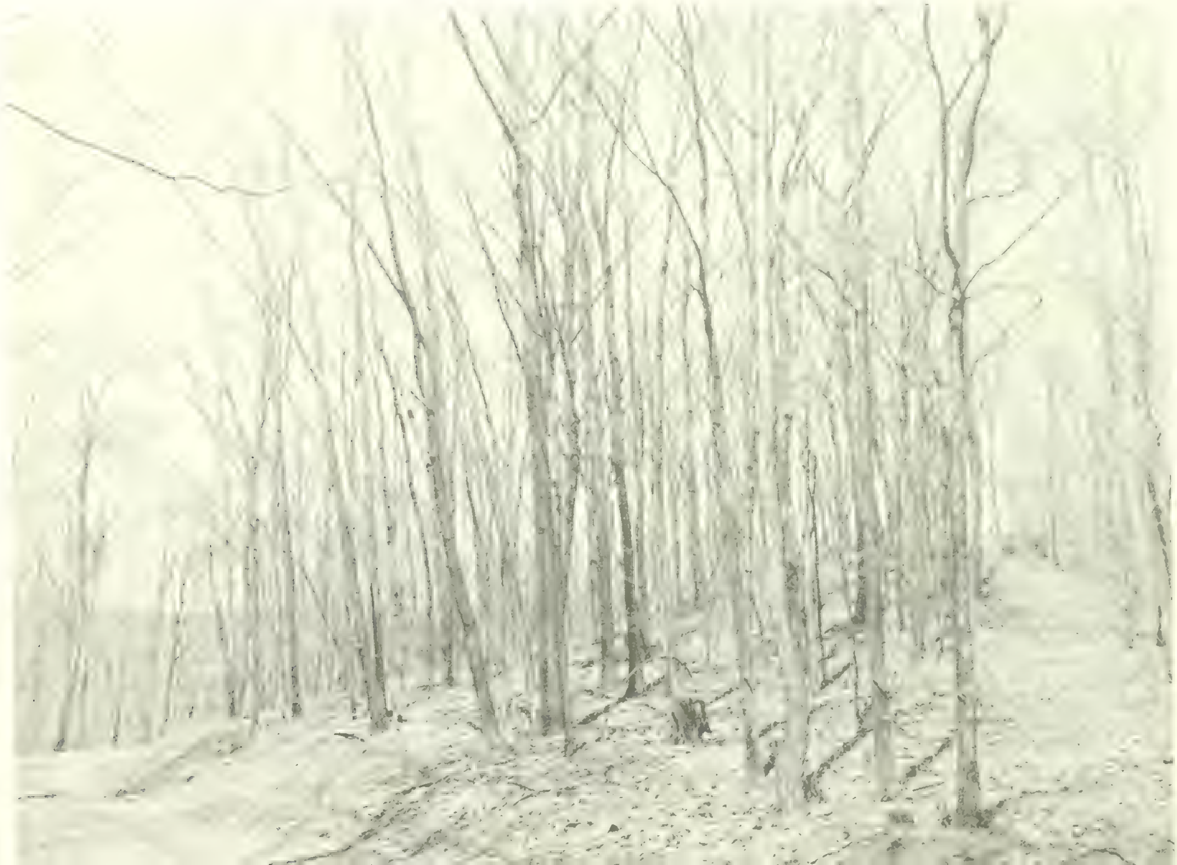


Table 1.—Summary of sprout data for all species, seasons of cut, and site index

Species	Site index	Season of cutting[a]	Number of stumps	Proportion of stumps with sprouts		Average number of sprouts per stump		Average height of dominant sprout[b]		Dominant sprout dbh
				1963	1972	1963	1972	1963	1972	1973
			No.	*Pct.*		*No.*		*Feet*		*Inches*
Red oak	80	D	50	98	94	34	7	3.1	25.6	2.6
Red oak	80	G	50	88	90	27	7	1.7	25.3	2.7
Red oak	60	D	50	98	100	38	7	3.9	26.2	2.8
Red oak	60	G	50	86	88	21	6	1.5	24.1	2.0
Black cherry	80	D	25	100	80	24	7	3.5	37.7	4.0
Black cherry	80	G	25	100	80	24	6	1.7	32.7	3.6
Yellow-poplar	80	D	36	97	89	42	5	4.0	32.4	4.1
White oak	60	D	26	85	85	35	4	2.4	19.6	2.4
Chestnut oak	60	G	47	81[c]	87	22	3	1.6	25.5	2.4

[a] D = Cut in dormant season; G = cut in growing season.
[b] Stumps with surviving sprouts.
[c] Some stumps produced sprouts the second year.

(dormant season), and the other plot was cut in June 1963 (growing season).

Sprout development was studied for 50 red oak stumps on each plot (table 1). On the excellent site, we also included for study 25 black cherry stumps on each plot and 36 yellow-poplar stumps on the dormant-season plot. On the fair site, we included 26 white oak stumps on the dormant-season plot and 47 chestnut oak stumps on the growing-season plot.

Dbh and vigor class of each tree were determined before cutting. Age was determined on the stump after the trees were felled. A 6-inch stump height was maintained, and stump wounding was avoided by careful felling and skidding.

There was a wide variation in parent tree dbh even though 97 percent of the red oak, 90 percent of the chestnut oak, 92 percent of the white oak, and all of the black cherry and yellow-poplar were between 50 and 55 years old. Parent tree dbh differed with each species: red oak ranged from 6 to 23 inches, white oak from 5 to 14 inches, chestnut oak from 5 to 18 inches, black cherry from 7 to 22 inches, and yellow-poplar from 6 to 22 inches.

The number of sprouts per stump and the height of the dominant sprout on each stump were recorded annually for the first 5 years, then at 7 years and again at 10 years. Dbh was recorded at the end of 7 and 10 years. Shifts in the dominant sprout from one measurement period to another were also recorded. Clear-stem length of the dominant sprout on each stump was measured at the end of 11 years.

The data were analyzed, using analysis of variance and regression techniques where applicable.

RESULTS

Proportion of Stumps Sprouting

By the end of the first growing season, more than 80 percent of all stumps had sprouted. At the end of 10 years, 80 percent or more of the study stumps still had sprouts (table 1).

There was no correlation between the proportion of stumps sprouting and site quality or season of cutting. However, a number of stumps, mostly from trees cut during the growing season, sprouted during the second growing season, which is why the 10-year data are higher than the 1-year data for some species (table 1).

Although there were only a few oak stumps in the 100-year-old class, most of the older stumps did not sprout.

For all species, there was an indication that a higher proportion of the stumps from trees smaller than 17.0 inches dbh produced sprouts, although the small number of larger trees precludes a firm conclusion on this point.

Number of Sprouts per Stump

For all species, the number of sprouts per stump decreased with years since cutting. The average number of sprouts per stump ranged from 21 to 42 at the end of the first growing season and from 3 to 7 at the end of 10 years (table 1).

The number of red oak and black cherry sprouts per stump was not correlated with season of cutting, even though there were fewer red oak sprouts at the end of the first year on stumps of trees cut during the growing season. We also found that the number of sprouts per stump for red oak at the end of the 1st and 10th year was not correlated with site index.

Parent-tree vigor and dbh for all species was not significantly correlated with the number of sprouts per stump surviving after the 1st or 10th year.

A large number of sprouts died during the first 5 years of the study. Mortality from the 6th through the 10th year was much less. The relationship of the number of surviving sprouts per stump at 10 years to the number present at the end of the first year is shown in figure 3.

Figure 3.—Average number of sprouts per stump over years since cutting.

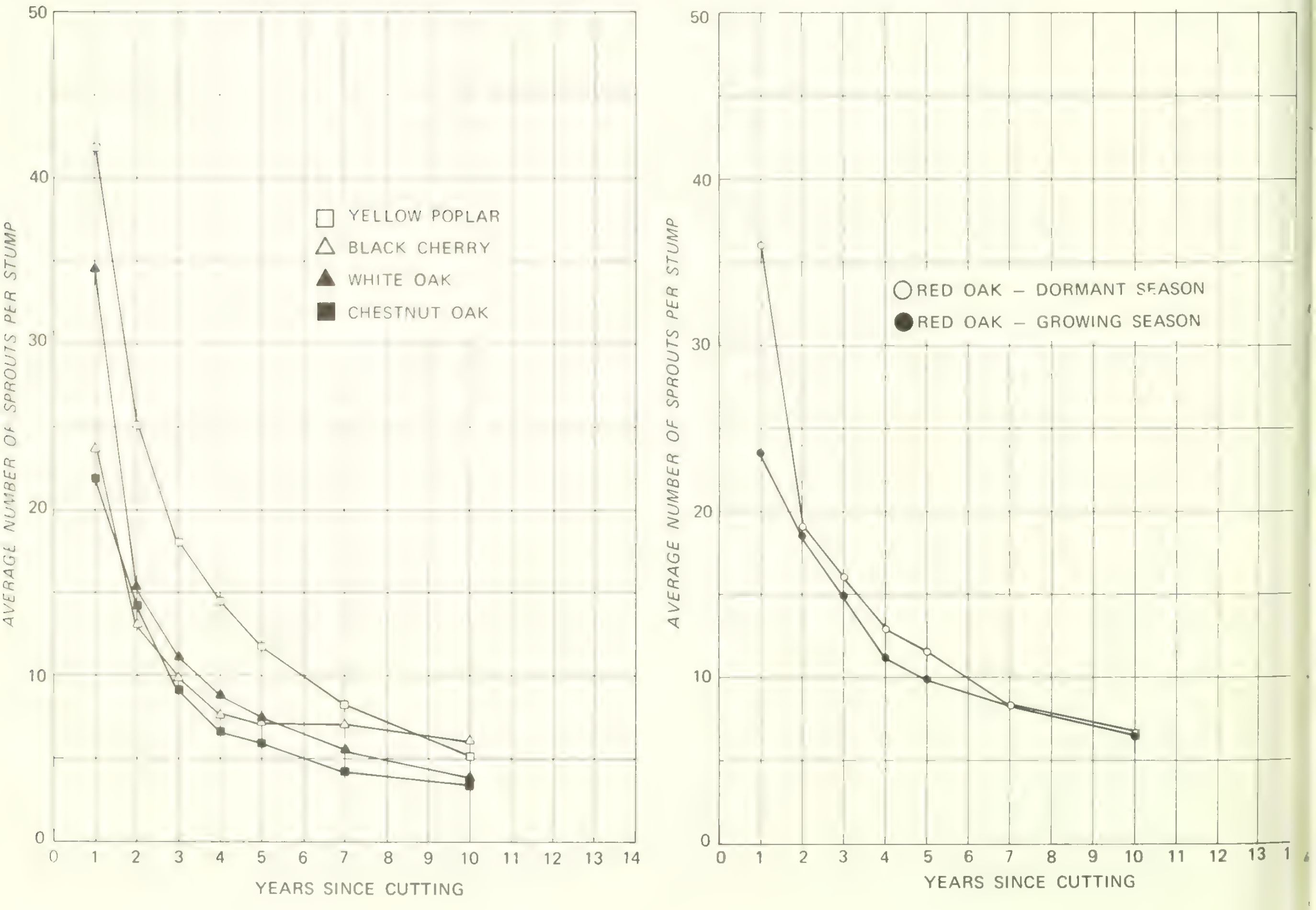
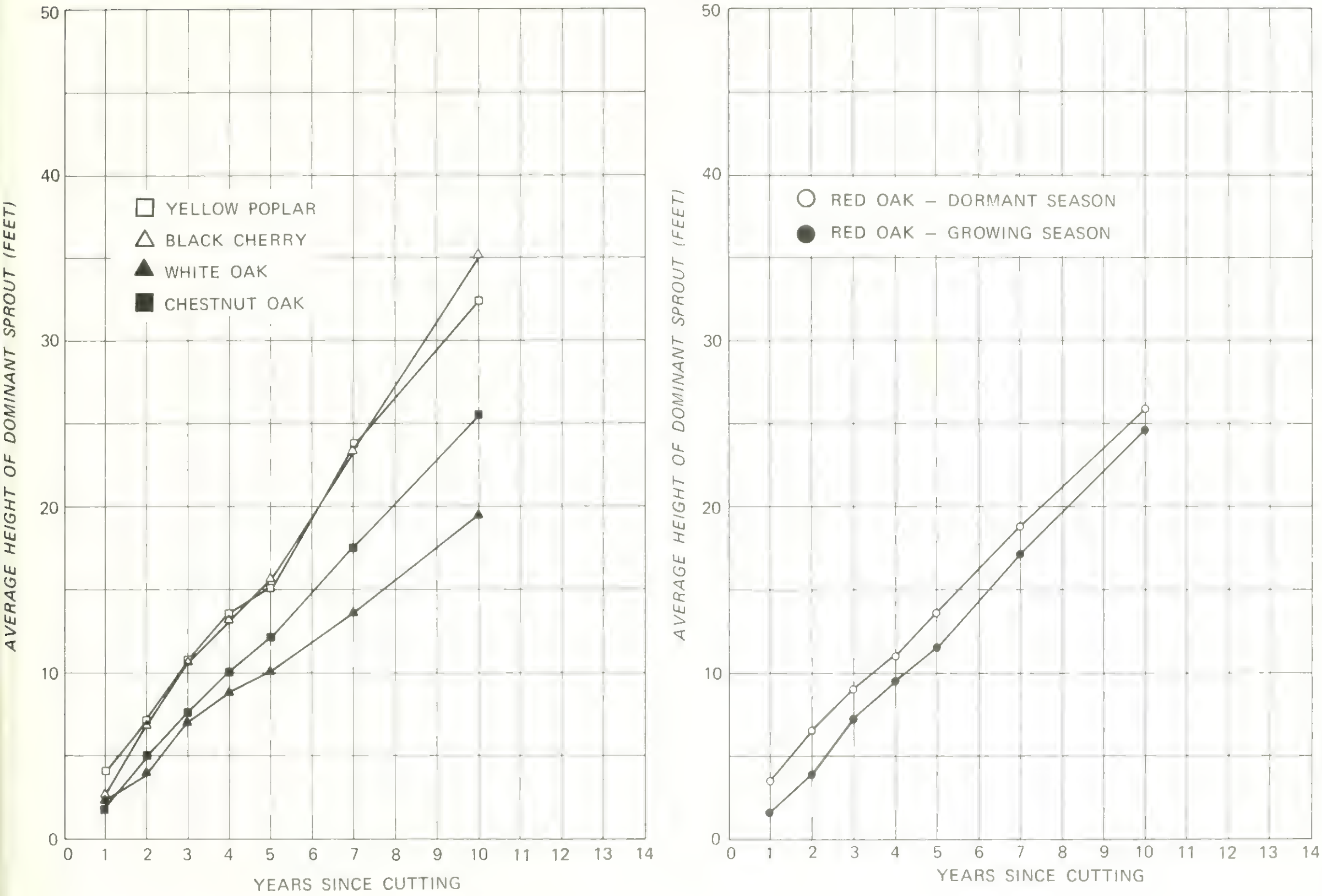


Figure 4.—Average height of dominant sprout over years since cutting.



Dominant-Sprout Height

For all species, dominant-sprout height at the end of 10 years was not correlated with parent-tree diameter or parent-tree vigor. For red oak, there was no correlation with site index or season of cutting; and for black cherry, dominant-sprout height was not correlated with season of cutting.

Ten-year average dominant sprout height ranged from 37.7 feet for black cherry to 19.6 feet for white oak (table 1 and fig. 4). Dominant sprouts on stumps of red oak and black cherry trees cut during the dormant season were about twice as tall as those cut during the growing season at the end of the first year; but 10 years later, there was no statistically significant difference.

Ten years after cutting, site index has not had an effect on dominant-sprout height of red oak.

On some stumps, the same sprout did not remain dominant from year to year. For red oak, shifts in sprout dominance occurred on about 50 percent of the stumps during the first 5 years (table 2). Even after 10 years, 12 percent of the red oak dominant sprouts were not the same ones that we had observed 3 years earlier. The number of shifts in dominant sprouts for the other species was frequent during the first 3 years but tended to taper off in later years.

Table 2.—Percentage of stumps having new sprout dominant since last observation

Species	Site index	Season of cutting[a]	Year of observation					
			1964	1965	1966	1967	1969	1972
Red oak	80	D	55	29	45	38	28	11
Red oak	80	G	58	76	47	18	9	11
Red oak	60	D	46	44	40	24	12	14
Red oak	60	G	60	53	48	24	14	12
Black cherry	80	D	52	54	0	14	5	25
Black cherry	80	G	78	65	38	10	25	15
Yellow-poplar	80	D	79	55	9	15	22	6
Chestnut oak	60	D	61	28	19	7	0	6
White oak	60	G	55	26	30	13	7	7

[a] D = cut in dormant season; G = cut in growing season.

Dominant-Sprout Dbh

Dominant-sprout dbh at 10 years ranged from 4.1 inches for yellow-poplar to 2.4 inches for white oak and chestnut oak (table 1). Red oak dominant sprouts on the fair site plot cut during the growing season tended to be smaller than those on the plot cut during the dormant season; but on the excellent site, there was no difference in dominant-sprout dbh between seasons of cutting.

The average dbh of black cherry sprouts from stumps cut during the dormant season was slightly larger than the average of those cut in the growing season, but this difference was not significant.

Dominant-Sprout Quality

Length of clear stem was used as the measure of stem quality. Small branches that we judged would drop off in natural pruning were disregarded. Large side branches and forks of about the same diameter as the main stem marked the upper limit of clear length. Because stem form changes rapidly at this age

Table 3.—Percentage of dominant sprouts by stem quality classes
[Based on number of stumps with surviving sprouts at 11 years]

Species	Site index	Season of cutting[a]	No. of stumps	Clear length of stem class (feet)[b]			
				12.0-17.0	17.1-21.0	21.1-25.0	25.1+
			No.	Percent			
Red oak	80	D	42	26	31	10	—
(good site)	80	G	44	20	41	20	5
Red oak	60	D	49	20	22	20	12
(fair site)	60	G	40	23	28	18	—
Total			175	22	30	17	5
Black cherry	80	D	20	—	10	15	65
(good site)	80	G	20	10	15	25	45
Total			40	5	13	20	55
Yellow-poplar (good site)	80	D	33	—	—	—	85
White oak (fair site)	60	D	22	55	9	9	—
Chestnut oak (fair site)	60	G	41	17	29	22	17

[a] D = cut in dormant season; G = cut in growing season.

[b] Small branches allowed but not major forks or large side branches that were judged to persist for a long time.

and usually for the better, we feel that this measure of quality was highly conservative.

About three-fourths of the red oak dominant sprouts had more than 12.0 feet of clear stem, and 52 percent had more than 17.0 feet (table 3). Only 5 percent of the red oaks had more than 25 feet of clear stem as compared to 85 percent of the yellow-poplars, 55 percent of the black cherry, and 17 percent of the chestnut oaks. None of the white oaks had more than 25 feet of clear stem.

DISCUSSION AND SUMMARY

For the species studied, we found that stumps from 50- to 55-year-old trees produced an abundance of sprouts the first year and that height and diameter growth of the dominant sprouts was very good during the 10-year period. In this study, stump size was not well correlated with tree age. Except for a few large red, white, and chestnut oaks that were 100 years old, all of the study stumps were from trees 50- to 55-years old. Large stumps sprouted as well as small stumps except for the few older and larger red oaks.

Previous studies have shown that the ability of oaks and sugar maple to sprout is inversely related to tree age and stump size *(Roth and Hepting 1943; Church 1960)*. Similarly Roth and Sleeth *(1939)* reported that low-origin oak sprouts were less likely to develop butt rot in later years than those that originated higher on the stump. True and Tryon *(1966)* reported that there was less butt rot in low-origin yellow-poplar sprouts and also less in sprouts from small stumps.

There tended to be more red oak sprouts at the end of the first year on stumps cut during the dormant season than on those cut in the growing season; but 10 years later, there was no effect of season of cutting.

Red oak and black cherry sprouts on the dormant-season cut plots were taller at the end of the first year than those on growing-season cut plots. After 10 years, there was no statistically significant difference, although dominant black cherry sprouts arising on stumps cut during the dormant season averaged about 5 feet taller.

We found that during the 10 years of the study, site quality was not a factor in red oak sprout height growth: sprouts on the fair site grew at about the same rate as those on the excellent site.

Between 75 and 90 percent of the sprouts died or were broken off in the first 10 years. This would suggest that thinning operations in sprout clumps might best be delayed for at least 10 years. Another factor in favor of waiting is that sprout dominance changes frequently in the early years, and it would be better to wait until dominance is more permanently expressed.

Our data show that there is usually one sprout that will develop into a good or excellent quality tree in the new stand (figs. 5, 6, 7, 8). For example, more than half of the dominant red, white, and chestnut oak sprouts have more than 17.0 feet of clear length after 11 years, ensuring at least one good log. For the black cherry and yellow-poplar, the potential is much greater. More than half of the cherry and 85 percent of the yellow-poplar have more than 25.0 feet of clear stem. In both species, the stems are well anchored, the crowns are well developed, and the trees are vigorous.

It does not seem likely that much butt rot will form in the sprouts. All trees were cut to a 6-inch stump height; and most of the surviving sprouts have low origins, thus greatly reducing the chance of butt rot.

In general, we can conclude from this study that if we are going to clearcut 50- to 60-year-old central Appalachian hardwood stands on sites similar to those in this study, a high proportion of the natural reproduction will be stump sprouts, which will overtop and suppress most seedling-origin reproduction in the first few years. About the only practical way to reduce sprouting at this age is to chemically treat the cut stumps. An alternative might be to postpone cutting until the trees are older, at which time the ability to sprout is reduced for many species. In our opinion, it would be difficult and costly to eliminate sprouts and attempt to increase the proportion of seedling origin stems after cutting middle-aged stands.

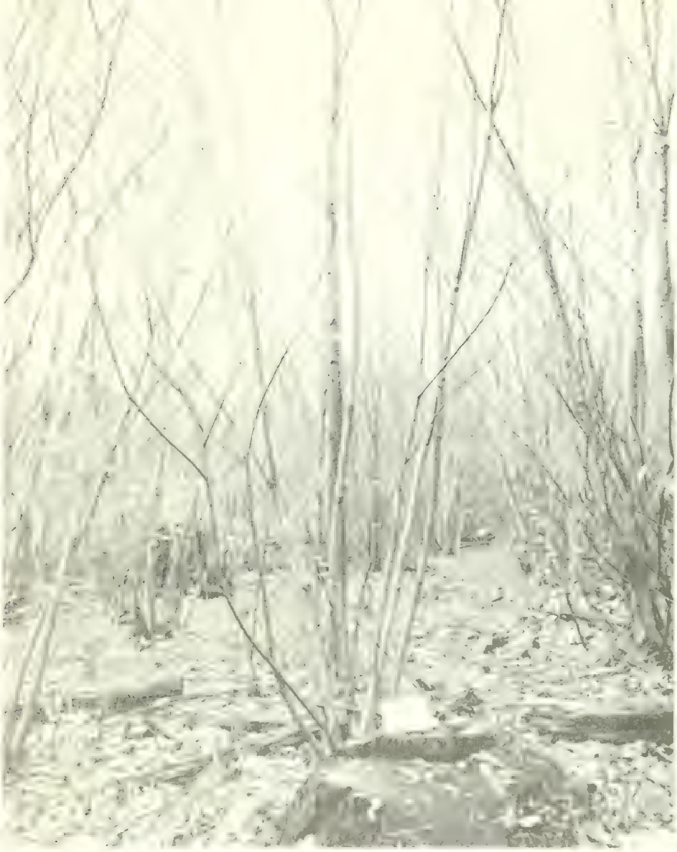


Figure 5.—A red oak sprout clump at 10 years.

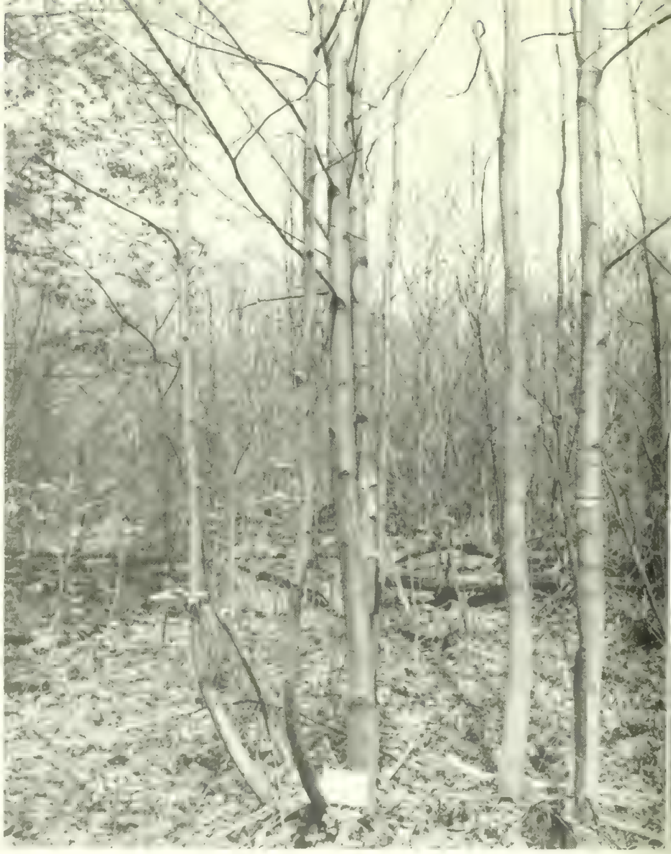


Figure 6.—A yellow-poplar sprout clump at 10 years.

Figure 7.—A chestnut oak sprout clump at 10 years.

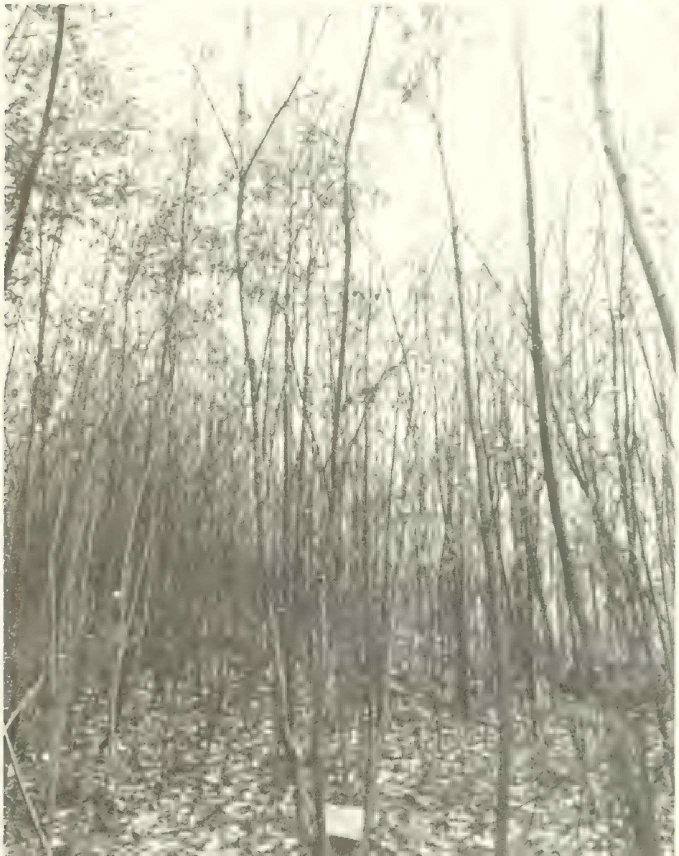
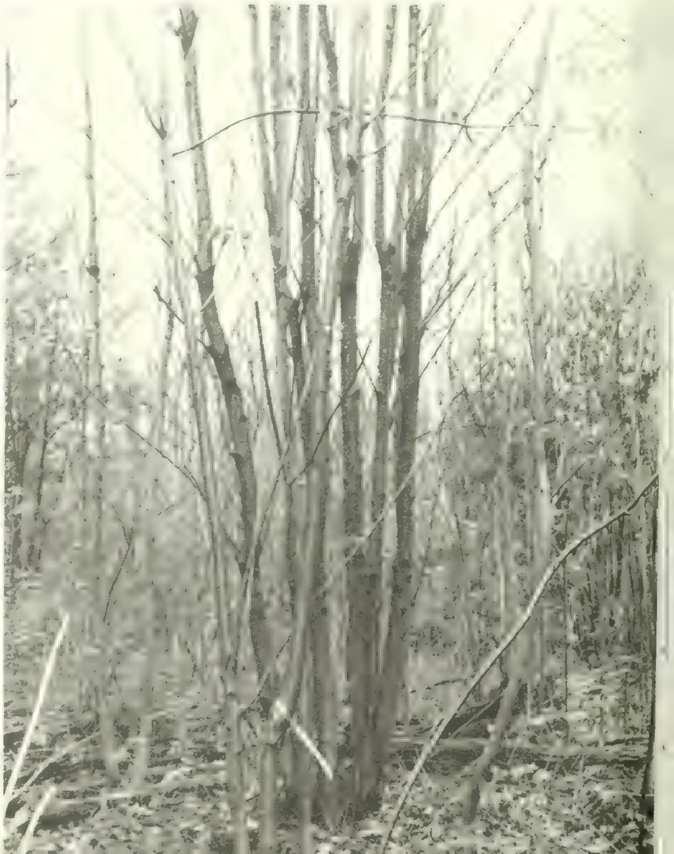


Figure 8.—A black cherry sprout clump at 10 years.



On the other hand, many of the sprouts have good form, are well anchored, and are potential for crop trees. If we wait until dominance within the clump is more permanently expressed and the weaker sprouts have died, there seems to be no reason why the best one or two sprouts per stump cannot be selected and treated as crop trees in the new stand.

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Wilbur F. LaPage
Paula L. Cormier
George T. Hamilton
Alan D. Cormier

USDA FOREST SERVICE RESEARCH PAPER NE-330
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Differential Campsite Pricing and Campground Attendance

ABSTRACT

Several changes in the characteristics of campers' visits were discovered by comparing camping permit data before and after the start of differential campsite pricing at a New Hampshire state park campground in 1973. Differentials included a premium charge for waterfront sites and a preferential rate for New Hampshire residents. Attendance by state residents increased significantly over the average for the preceding 2 years. Total revenue increased by 61 percent. The preferential rates did not produce longer visits or more frequent repeat visits by state residents. Use of waterfront sites did not decline in response to premium rates. Significant declines in visit length and party size were noted, but appear to be independent of the fee policies.

Keywords: Campsite pricing, recreation expenditures, differential fees, camper behavior, park attendance, fee policies, New Hampshire State Parks.

THE PROBLEM

THE USE OF FEES as a management tool, for regulating resource use and modifying visitor behavior in addition to generating revenue, is a recurring recommendation in outdoor recreation literature. It has been suggested, for example, that raising fees might reduce crowding at peak times and in heavily used areas *(Clawson and Knetsch 1966)*; that reducing or even eliminating fees might produce a more even workload in periods when attendance is traditionally low *(Lime and Stankey 1971)*; and that preferential fees for state residents and differentials based upon site quality may be more equitable than flat rates *(LaPage 1968)*.

Competitively based differentials obviously exist among some commercial recreation enterprises. Differentials within park systems—such as higher fees at campgrounds that provide swimming facilities—have existed for many years. However, reports of the success of these practices in achieving managerial goals are apparently nonexistent, and experimental studies of the effects of differential fees are rare.

Canavan *(1973)* reported that camping parties did adjust their use of waterfront sites in response to a $2 fee differential at Wells State Park in Massachusetts, during periods of less than peak use in the summer of 1972. Use of waterfront sites decreased by as much as 30 percent in some months. More than 60 percent of the campers visiting waterfront sites felt that the extra charge was justified. The $2 differential at Wells State Park was created by reducing the standard fee of $3 to $2 at 30 inland sites, and increasing it to $4 at 25 waterfront sites. The impact on total revenue was minimal, since the average site price remained near the 1971 level. The applicability of these findings may be limited because of the reduction in price at inland sites. A more common practice might be to increase the price of both types of sites, or to raise the waterfront price and hold the inland site price constant.

Before applying differentials based on site quality, an administrator might want to know how the differentials could affect his workload. For example, will there be more requests to switch campsites after a busy weekend, requiring rewriting of permits and correction of records? Will the frequency of permit extentions be affected? What will be the effect upon average visit lengths? Each of these factors may influence the amount of service required and may necessitate changes in the campground maintenance routine.

Fee differentials between in-state and out-of-state residents raise added questions. What will be the change (if any) in the proportions of resident and nonresident campers, the frequencies and lengths of their visits? In 1973, four states—Idaho, Maine, New Hampshire, and Vermont—established differential camping fees based on residence. An analysis of 1972 and 1973 camping permits for these four state park systems might provide some answers to these questions.

THE STUDY SITUATION

Before New Hampshire announced its residence differential, we had established a system for computer analysis of all information on camping permits at Pawtuckaway State Park in southeastern New Hampshire. A search program identified all permit extensions and consolidated the permits written into total visits, making it possible to determine visit lengths accurately. The program also summarized data on campers' origins, repeat visits during the season, and moves from one campsite to another during a single visit to the campground.

The 169 campsites at Pawtuckaway State Park are distributed along a waterfront and inland to a distance of about 900 feet from the lakeshore. Because of the obvious differences in site quality, a second differential was established at this park between the 61 waterfront and the 108 inland sites. Before 1973, camping rates were $1.00 per person over 12 years of age. This rate resulted in an average campsite fee of $2.44 per night. With the implementation of the dual differential in 1973, the new family rates were:

	Resident	*Nonresident*
Inland sites	$3.00	$4.00
Waterfront sites	4.00	5.00

In addition to the fee changes in 1973, New Hampshire state parks adopted a policy of reserving a minimum of 20 percent of their campsites for New Hampshire residents. At Pawtuckaway, a block of 33 sites (21 waterfront and 12 inland), served by a single access road, were set aside for the exclusive use of New Hampshire residents.

The analyses of 1971 and 1972 camping permits at Pawtuckaway produced both a system for handling permit data and several base-line measures of campground use. These data made it possible to measure the impacts of the major policy changes in 1973 on such campground characteristics as visit length, camper origin, and occupancy rates of waterfront and inland sites.

METHOD OF STUDY

All information from camping permits issued during 1971, 1972, and 1973 was transferred to data cards. Because many campers prefer to register for only 1 or 2 days at a time even though they may be planning to stay for the maximum allowable 2 weeks, it was necessary to consolidate all reregistrations into single visits. During 1971 and 1972, nearly one-third of all campers extended their stay at least once during a single visit.

During 1971 and 1972, approximately 10 percent of permit extensions involved a change of campsite. Despite this low frequency, we were interested in maintaining a record of site-switching. This record provided an opportunity to discover any relationship between fee differentials and the frequency of site-switching: (1) within the waterfront zone, (2) within the inland zone, and (3) between zones.

As a byproduct of consolidating permit extensions and plotting site-switching, we developed a measure of the frequency of early departures. During 1972, over 350 parties left at least 1 day before their permits expired. Refunds are not made for early departures, and we were interested in determining whether early departures would decline when fees were increased in 1973.

The main computer program for this study provided a site-by-site annual summary for each zone, listing: total registered parties, total registered persons, total adults, total days the site was occupied, total days on which the site was occupied by two parties on the same day, percentage of capacity use, a frequency listing of visit lengths and average visit length for each site, a frequency listing of party sizes, and average party size. The waterfront and inland zone summaries also provided frequencies of site use by resident and nonresident campers, total dollar income for the zone, the average income per site-day, and a season-long percentage occupancy graph.

A second program, in addition to summarizing site-switching, also provided a summary of repeat visits (during the season) by campers' home states, a summary of types of equipment used by residents and nonresidents, and a summary of the only item of data not provided directly by the permit, local or nonlocal origin of visitors. A local visitor was defined as one living within 50 miles of the park. (Copies of both programs and output samples are available from the authors upon request.)

RESULTS

Attendance and Occupancy

Despite the increased cost to campers that resulted from the 1973 fee differentials, total campground visits increased by 7 percent and the number of permits issued was up 3 percent over the 1971-72 averages. But while the volume of business and park income increased, there were slight declines in total persons and in site occupancy rates for the 1973 season (table 1).

During the 3 years of the study, the average party size, of both resident and nonresident campers, decreased by nearly one-third per-

Table 1.—Occupancy and attendance statistics, 1971-73, Pawtuckaway State Park

Item	Average 1971-72	1973	Difference
	No.	*No.*	*Percent*
Permits issued	6,119	6,285	+3
Permit extensions	2,014	1,905	−5
All parties	4,105	4,380	+7
Total persons	15,954	15,715	−1
Average party size	3.89	3.59	−8
Occupied site nights	13,149	12,427	−5
Parties turned away	1,007	597	−41
Average percent occupancy:	*Percent*	*Percent*	*Percent*
Waterfront (61 sites)	70	66	−4
Inland (108 sites)	53	45	−8
All (169 sites)	60	53	−7

son. This decline is more than three times that reported by the Census Bureau for family size during the same period *(U.S. Bureau of the Census 1973)*.

The sharp reduction in party size may be a reflection of a shift in the camping public toward younger campers and more nonfamily camping groups. Further evidence of such a shift is the 6-percent increase in tent campers in 1973, over the 55 percent reported in 1972. (No comparison with 1971 is possible because camping equipment was not recorded on permits until 1972).

The average percentage of occupancy declined in 1973 by 4 percent in the waterfront zone and by 8 percent in the inland zone. These declines in occupancy, without a similar drop in visits, reflect the effect of a gradually eroding average length of visit (table 2). Although permit extensions were slightly less frequent in 1973, their effect was nearly balanced by a decline in early departures (table 3), so that the shorter visits appear to be the result of a long-term trend rather than a direct effect of the increase in fees. Average visit length declined by approximately ¼ day during each year of the study at both waterfront and inland sites. The suggestion of a long-term trend is supported by an examination of earlier sample surveys of campers at this park, which reported average visit lengths of 6.4 to 7.6 days in 1967, based on samples of 107 and 40 campers respectively *(LaPage 1971, Jansen et al. 1971)*. The shorter 1973 visit may, again, be a reflection of a change in the camping clientele from family groups toward smaller, younger, and unrelated camping groups.

Average visit lengths for campers at waterfront sites were consistently longer, in every year, than those of campers at inland sites. The higher cost of waterfront sites in 1973 did not appear to reduce average visit lengths; the reduction from the 1971-72 average was the same in both zones.

Throughout the 3 years, the average camping visit of a New Hampshire resident was over ½ day longer than that of a nonresident. The preferential rates given New Hampshire residents in 1973 did not increase their average length of visit.

Table 2.—Average visit length in days for all campers, 1971-73

Category	1971	1972	1973
Waterfront campsites	4.19	3.89	3.62
Inland campsites	2.96	2.79	2.46
N. H. residents	3.78	3.65	3.23
Nonresidents	3.14	2.92	2.60
Campground totals:*	3.49	3.25	2.95

* Campground totals are slightly higher than would be derived by weighting the averages for each class of sites because zone averages include two shorter visits for every party that changed its campsite.

Table 3.—Visit extensions and early departures of campers in 1972 and 1973

Item	Percentage of total parties		
	1972	1973	Difference
Number of extensions:			
None	69	74	+5
One	20	17	−3
Two	7	6	−1
3 to 13	4	3	−1
Days left early			
None	93	96	+3
One	5	3	−2
Two or more	2	1	−1
			Percent
Paid camper days not camped	1,411	696	−51
Cost to campers*	$874	$725	−17

* Estimated from average cost per site of a night's camping of $2.44 in 1972 and $4.05 in 1973.

Origin of Visitors

The number of nonresident visitors to the park dropped by 4 percent in 1973, while the number of New Hampshire parties increased by 36 percent over the previous 2-year average. During 1971 and 1972 the proportion of visitors from New Hampshire was 27 percent; in 1973 it went up to 35 percent. Visitors from Massachusetts dropped from 44 percent to 41 percent, and Canadians from 4 percent to 2 percent. Local (50-mile radius) visits increased from 40 to 45 percent.

The preferential fees for residents did not seem to encourage repeat visits during the season. Fifteen percent of the New Hampshire visitors made two or more camping trips to Pawtuckaway each year in 1971 and 1972. In 1973, the proportion of New Hampshire residents who made repeat visits increased to 18 percent. For all visitors, the repeat visit rate was a constant 11 percent for each of the 3 years.

The proportions of residents and nonresidents who used the waterfront zone did change significantly during 1973. With 34 percent of the waterfront sites reserved for New Hampshire residents, use by residents increased from 31 percent in 1971-72 to 44 percent of the waterfront zone use in 1973 (table 4).

Table 4.—Percentage of visitors at waterfront and inland sites who were not residents of New Hampshire, 1971 to 1973

Nonresident occupancy of—	Average 1971-72	1973	Change
Waterfront campsites	69	56	−13
Inland campsites	74	70	−4
All sites	73	65	−8

Site-Switching

Moving from one site to another during a single visit is not encouraged by the park management. However, it does occur when families who want to camp near each other do not arrive at the same time; and it is often done in conjunction with a permit extension, when a camper wishes to improve his location during an extended visit. Because it does occur, we felt that site-switching might be responsive to fee differentials, when some campers seek to improve their locations and others attempt to economize by moving from a premium waterfront site to a less expensive inland site. Site-switching might also increase with reduced occupany levels and a resulting increase in opportunities.

The total incidence of site-switching was relatively constant from year to year (table 5). However, there is slight evidence that the premium rate for waterfront sites may have discouraged a small amount of movement into the waterfront zone from the inland zone. It also appears that the premium rate may have encouraged more shopping around within the waterfront zone. There was no significant movement from more expensive sites to less expensive ones.

Table 5.—Incidence and direction of site-switching, 1971 to 1973

Number of moves	Average 1971-72	1973	Change
	No.	*No.*	*Percent*
From waterfront to waterfront	28	40	+43
From waterfront to inland	10	7	−30
From inland to waterfront	96	84	−13
From inland to inland	59	60	+ 2
All moves	193	191	− 1

Revenue and Cost to Campers

The average cost of a campsite per day for all classes of sites, for resident and nonresident visitors alike, was $4.05 in 1973. Waterfront sites averaged $4.58 per day, inland sites $3.75 per day. The average cost of campsites of all classes during the previous 2 years was $2.44. Therefore the average increase in income to the park for each occupied waterfront campsite in 1973 was $2.14 per day; for inland sites it was $1.31.

The dollar income from camping permits increased dramatically in 1973; income was 61 percent higher than the preceding 2-year aver-

Table 6.—Revenue from camping permits, 1971 to 1973, Pawtuckaway park

Source	Average 1971-72	1973	Increase
			Percent
Waterfront sites (61)	$14,083	$26,461	+88
Inland sites (108)	18,883	26,651	+41
All sites (169)	$32,966	$53,112	+61

age of $33,000 (table 6). The income from waterfront sites increased by 88 percent, while that from inland sites increased by 41 percent. The portion of the $20,146 increase in campground income attributable to waterfront premiums is 29 percent, 39 percent is due to the nonresident differential, and 32 percent is a direct result of changing the fee basis from number of adults to campsites. The per-site charge was, in effect, a price increase of $0.56, from the average of $2.44 in 1972 to a minimum, for all campers, of $3.00 in 1973.

Camper Reactions

A supply of printed forms inviting comment about the differential fee systems at Pawtuckaway State Park was conspicuously displayed at the camper registration counter throughout the 1973 camping season.

Sixteen comments were returned; four of them were totally unrelated to camping fees, and two commended the idea of the differential. One nonresident objected to the differential and one resident objected to the waterfront premium charge. Three nonresidents suggested that the resident fee be applied to nonresidents who were registering for 1 week or longer. The remaining five comments questioned the complexity of the system and the need for it. A complaint rate of less than 2 per thousand parties seems to be an acceptable endorsement of the changed fee policies.

Although the reactions of would-be campers who must be turned away at the gate because of capacity crowds are difficult to document, the 41-percent reduction in turn-aways during 1973 (table 1) appears to be a desirable side effect of the fee changes. Differential campsite pricing, or at least more realistic campsite pricing, seems to result in improved equity not only in resource allocation among users but in reducing the number of disappointed nonusers as well.

CONCLUSIONS

Differential fees based on residence of campers and inherent campsite attractiveness were accepted by campers, and did not produce any significant change in overhead costs, numbers of visits, length of visits, or site-switching. A redistribution of resident and nonresident use of premium waterfront sites occurred, but this was, at least in part, a result of reserving 34 percent of all waterfront sites for the exclusive use of New Hampshire residents. The premium charges at heavily used waterfront sites did not result in a significant reduction in use.

Incidental findings from the study were: (1) an apparent trend toward smaller camping parties and shorter visits, and (2) a significant increase in tent camping accompanied by a decrease in recreational vehicle camping.

This experiment in differential campsite pricing, using available data, is one example of the kind of recreation research that can be carried out through the combined efforts of park administrators and researchers. Policies and administrative practices of public agencies are constantly changing, and their records, before and after those changes, are frequently available for analysis. In many instances, valuable information for an agency contemplating a major policy change may be buried in its own past records.

This experiment, though conducted at a public park, has important implications for the commercial campground industry. Approximately one-third of the campsites in this study were considered worth a premium. The premium rates alone increased average park earnings by 29 percent. Use of premium sites declined by only 4 percent; and that decline appears to reflect a market trend that is independent of local prices.

Differential campsite pricing is not a common practice at the Nation's 9,000 commercial campgrounds. However, if one-third of the campsites in each campground could qualify for premium rates because of superior quality, condition, or features, many of the industry's marginal operations might become profitable. In New Hampshire alone, the 212 operating campgrounds (averaging 67 sites each) may have as many as 4,700 premium sites that could rent for an additional $1 per day through the 100-day season. And, since the best sites are the ones that are most likely to be 100-percent occupied, differential pricing could theoretically generate an additional $470,000 per season for the state's commercial campground industry.

Differential campsite pricing at the 5,500 campgrounds provided at public expense across the country might lead to more realistic pricing, better park funding, and a more equitable use of public campsites if the results of this study are a valid indication of camper response.

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ABSTRACT

Sampling of forest tree foliage for nutrient analyses is commonly restricted to specific and often difficult-to-reach locations such as the uppermost sun leaves growing on the south side of the crown. A study of 60-year-old red, white, chestnut, and scarlet oaks growing near Parsons, West Virginia, suggests that the easier-to-reach foliage from the lower crown is equally well suited for nutrient sampling. In this study, 10 individuals of each species were sampled. Foliage samples were taken from the terminal shoot, from each cardinal point in the upper unshaded section of the crown, from each cardinal point in the lower section, and from interior crown positions. Samples were analyzed for N, P, K, Ca, Mg, Mn, and Fe; and variation within trees, among trees of similar species, and between species was determined for each element. Direction of foliage orientation within the crown did not influence nutrient composition. Concentrations of K, Ca, and Mg were generally higher in the lower than in the upper crown, while N, P, Mn and Fe concentrations were unrelated to position. Tree-to-tree variation was approximately the same for all crown positions. Many differences in foliar nutrient composition occurred among species.

PLANT ANALYSIS is a potentially useful technique for diagnosing nutrient deficiencies and predicting fertilizer needs of forest trees. Its reliability for these purposes, however, depends upon careful standardization of sampling procedures.

In deciduous trees, important differences in nutrient composition can be attributed to the location of the foliage in the crown. Differences occur among neighboring trees of equal size, age, and dominance class *(Chandler 1939, Guha and Mitchell 1966, Hoyle 1965, Tamm 1951, and Wallihan 1944)*. Because sampling large trees is expensive and physically difficult, it is essential to have reliable estimates of: (1) within-tree variation, including that associated with different crown positions; and (2) tree-to-tree variation within stands. Having this information, we can begin to develop sampling guidelines so that the desired accuracy of foliar analyses can be attained with a minimum number of samples.

The objective of our study was to obtain information about within-tree, between-tree, and between-species variation in nutrient composition for an even-aged upland oak stand growing on a uniform site in the northern Appalachians.

METHODS

The study was located in a 60-year-old even-aged upland oak stand on the Fernow Experimental Forest near Parsons, West Virginia. Species composition was predominantly of red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), chestnut oak (*Q. prinus* L.), and scarlet oak (*Q. coccinea* Muenchh.), with lesser numbers of black gum (*Nyssa sylvatica* Marsh.), red maple (*Acer rubrum* L.), and sassafras (*Sassafras albidum* Nutt.). The stand had a site index of 66 for upland oaks *(Schnur 1937)* and was tightly closed, averaging 217 stems per acre (531 stems/ha) over 5.0 inches dbh (12.7 cm) with a basal area of 110 square feet per acre (10.2 square meters/ha). The soil was a well-drained Calvin silt loam (Typic Dystrochrept) about 30 inches (76 cm) deep to bedrock and topographically uniform over the entire study site.

Ten dominant-codominant red, white, chestnut, and scarlet oaks (40 trees) located within a 1.5-acre area (0.61 ha) were climbed and sampled during a 12-day period in late August. Foliage from each tree was collected from the terminal shoot, from each cardinal point (north, south, east, west) in the upper unshaded portion of the crown, from cardinal points in the lower crown, and from interior positions. Each foliar sample, except from interior positions and terminal shoots, came from one branch and consisted of 25 mature leaves that were on current-season shoots located near the periphery of the crown. Interior samples of 25 leaves were collected as a composite sample from four smaller branches in the central portion of the inner crown; they represented true shade leaves. The terminal sample consisted of 25 mature leaves from the main terminal leader of the tree.

Leaf-blade samples, with petioles removed, were dried at 70°C, weighed, and ground to pass a 20-mesh screen. Nitrogen was determined by the Kjeldahl procedure. Phosphorus was determined colorimetrically by the vanadomolybdophosphoric yellow method; and K, Ca, Mg, Mn, and Fe were determined by atomic absorption from digests obtained by wet-ashing with nitric and perchloric acids. Nutrient levels were expressed as concentration (percent of dry weight) and also as content (milligrams per leaf). All data were tested for differences at the 5-percent level by using the Scheffé test *(Scheffé 1959)*.

RESULTS AND DISCUSSION

Within-Tree Variation

Positional differences.—Cardinal direction, within either the upper or lower crown, had no consistent effect on foliar dry weight, nutrient concentration, or nutrient content per leaf for any of the species (tables 1 and 2). Therefore, orientation data were pooled by crown position for each tree, and these pooled data were used in all other analyses (unbalanced design considered). Leaf weight and nutrient-concentration levels were often associated with crown position, but nutrient-content levels were less closely related to crown position. Positional differences were greatest for red oak, intermediate for white oak, and least for scarlet oak and chestnut oak (tables 1 and 2).

Leaf dry weight showed a decreasing trend from terminal through interior positions for all species. Differences were greatest for red oak and white oak and minimal for chestnut oak and scarlet oak. White oak leaves from interior positions weighed significantly less than those from other positions. Interior leaves of red oak weighed less than those from terminal and upper positions, and leaves from lower-crown positions weighed less than terminal leaves.

Concentrations of K, Ca, and Mg generally differed among crown positions for most species; but concentrations of N, P, Mn, and Fe were unrelated to position. K concentrations were higher in leaves from interior positions than in leaves from other crown locations; K concentrations were also generally higher in the lower crown than in the upper. Similarly, Ca and Mg concentrations were usually higher for the lower-crown and interior positions than for terminal and upper locations.

These results indicate that, for purposes of comparison, samples that are to be analyzed for weight and concentrations of K, Ca, and Mg must come from specific crown positions; for samples to be analyzed for N, P, Mn, and Fe, it is not necessary to control sampling position.

Nutrient-content data for all species showed no consistent differences due to position for any of the nutrients. However, red, scarlet, and chestnut oaks did have higher K contents in leaves from the interior positions than from terminal, upper, and lower positions. Red oak showed a decreasing trend for content of N, P, Ca, and Mn from terminal through upper, lower, and interior positions.

Species differences.—Differences in foliar weight and nutrient composition among the four species were apparent (appendix, tables 7 and 8). Red oak had the heaviest leaves and consistently had the highest nutrient content for all seven elements. White and scarlet oak foliage weighed least and usually had lower nutrient contents than did red or chestnut oaks. Concentrations of N, P, and Ca differed only slightly among red, chestnut, and white oaks; but these concentrations were significantly higher than values for scarlet oak. K and Mg concentrations were similar for red and chestnut oaks, and these were higher than concentrations occurring in white and scarlet oak foliage. Mn concentrations were significantly higher for red and scarlet oaks than they were for chestnut and white oaks. There were no differences among species for Fe concentrations.

Sampling requirements.—Within-tree variation for leaf weight, nutrient concentration, and nutrient content was usually somewhat less in the upper crown than in the lower (appendix, tables 9 and 10). Differences in variability between upper and lower crown positions were greatest for leaf weight and least for concentration. The higher variance shown by the data for content is the result of additional variation associated with leaf weights. These results show that samples obtained from either the upper or lower crown positions will require foliage from more than one branch for accurately estimating individual tree nutrition, and that a greater sampling intensity is necessary for estimating nutrient content with the same precision level as concentration.

Sample-size requirements for individual trees vary by species, specific nutrients, crown position, and the sampling accuracy that is desired (tables 3 and 4). Sampling the easier-to-reach foliage in the lower crown requires only the collection of leaves from a few more branches than if sampling is done from the

Table. 1.—Dry weight and nutrient concentration of foliage from different crown positions for red, white, chestnut, and scarlet oaks [1]

Species	Terminal foliage	Upper foliage	Lower foliage	Interior foliage	Remarks
		LEAF DRY WEIGHT *(grams)*			
Red oak	0.86a	0.81ab	0.76bc	0.73c	General decrease from terminal through interior.
White oak	.52a	.48a	.47a	.40b	
Chestnut oak	.63a	.64a	.64a	.60a	
Scarlet oak	.52a	.52a	.49a	.48a	
		NITROGEN *(percent)*			
Red oak	2.52a	2.52a	2.48a	2.48a	No appreciable change.
White oak	2.47a	2.56b	2.54ab	2.56b	
Chestnut oak	2.48a	2.45a	2.47a	2.42a	
Scarlet oak	2.26a	2.24a	2.16b	2.21ab	
		PHOSPHOROUS *(percent)*			
Red oak	.14a	.14a	.13a	.14a	No appreciable change.
White oak	.14a	.15ab	.15b	.17c	
Chestnut oak	.14a	.14a	.14a	.14a	
Scarlet oak	.12a	.12a	.12a	.12a	
		POTASSIUM *(percent)*			
Red oak	1.02a	1.04ab	1.07b	1.21c	Increase from terminal through interior; interior significantly higher than other positions.
White oak	.74a	.73a	.76a	.92b	
Chestnut oak	.91a	.90a	.98a	1.16b	
Scarlet oak	.68a	.70a	.73a	.92b	
		CALCIUM *(percent)*			
Red oak	.55a	.55a	.60b	.58ab	Increase from terminal through interior.
White oak	.42a	.47b	.58c	.61c	
Chestnut oak	.55a	.54a	.61b	.62b	
Scarlet oak	.42a	.44ab	.47b	.44ab	
		MAGNESIUM *(percent)*			
Red oak	.13a	.13a	.14b	.14b	Increase from terminal through interior.
White oak	.08a	.09a	.10b	.11c	
Chestnut oak	.11a	.11a	.13b	.13b	
Scarlet oak	.09a	.10a	.10a	.10a	No appreciable change.
		MANGANESE *(percent)*			
Red oak	.18a	.18a	.18a	.16b	No appreciable change.
White oak	.10a	.10ab	.11ab	.11b	
Chestnut oak	.11a	.11a	.12a	.11a	
Scarlet oak	.16a	.17a	.16a	.14b	
		IRON *(ppm)*			
Red oak	94a	95a	99a	101a	No appreciable change.
White oak	79a	82a	89ab	97b	
Chestnut oak	92a	88a	94a	109b	
Scarlet oak	89a	87a	82a	83a	

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[1] Terminal and interior values are the averages of 10 samples obtained from 10 different trees. Lower and upper values are the averages of 40 samples (4 samples from each of 10 different trees). Each individual sample contained 25 leaves. Values in each *ROW* followed by the same letter are not significantly different (Scheffé test, $P < .05$).

Table 2.—Nutrient content (milligrams per leaf) of foliage from different crown positions for red, white, chestnut, and scarlet oaks [1]

Species	Terminal foliage	Upper foliage	Lower foliage	Interior foliage	Remarks
NITROGEN					
Red oak	21.57a	20.29ab	18.97bc	18.12c	Decrease from terminal through interior.
White oak	13.00a	12.40a	12.08a	10.38b	No change due to position.
Chestnut oak	15.56a	15.54a	15.84a	14.52a	
Scarlet oak	11.77a	11.61a	10.69a	10.50a	
PHOSPHORUS					
Red oak	1.17a	1.10ab	1.02bc	0.99c	Decrease from terminal through interior.
White oak	0.76a	0.72ab	0.72ab	0.67b	No change due to position.
Chestnut oak	0.86a	0.87a	0.91a	0.87a	
Scarlet oak	0.64a	0.64a	0.58a	0.59a	
POTASSIUM					
Red oak	8.80ab	8.45ab	8.19a	8.89b	No difference between terminal, upper or lower, but interior significantly higher than other 3 crown positions, except for white oak.
White oak	3.92a	3.54a	3.59a	3.71a	
Chestnut oak	5.70a	5.62a	6.27ab	6.96b	
Scarlet oak	3.51a	3.58a	3.62a	4.32b	
CALCIUM					
Red oak	4.79a	4.49ab	4.56ab	4.27b	No consistent trend.
White oak	2.21a	2.27ac	2.73b	2.50bc	
Chestnut oak	3.44a	2.27a	2.33a	3.77a	No change due to position.
Scarlet oak	2.15a	3.43a	3.85a	3.77a	
MAGNESIUM					
Red oak	1.09a	1.03a	1.03a	1.01a	No change due to position.
White oak	0.43a	0.42a	0.46a	0.44a	
Chestnut oak	0.68a	0.68a	0.81a	0.81a	
Scarlet oak	0.47a	0.49a	0.48a	0.45a	
MANGANESE					
Red oak	1.55a	1.45ab	1.36bc	1.21c	Decrease from terminal through interior
White oak	0.54a	0.51ab	0.53ab	0.47b	No change due to position.
Chestnut oak	0.69a	0.69a	0.73a	0.69a	
Scarlet oak	0.80a	0.86a	0.80a	0.68b	
IRON					
Red oak	0.082a	0.078a	0.079a	0.067a	No change due to position.
White oak	0.041a	0.039a	0.042a	0.400a	
Chestnut oak	0.057a	0.055a	0.060a	0.065a	
Scarlet oak	0.046a	0.045a	0.040a	0.039a	

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[1] Terminal and interior values are the averages of 10 samples obtained from 10 different trees. Lower and upper values are the averages of 40 samples (4 samples from each of 10 different trees). Each individual sample contained 25 leaves. Values in each *ROW* followed by the same letter are not significantly different (Scheffé test, $P < .05$).

Table 3.—Number of samples required from individual trees for estimating dry weight and nutrient concentrations at selected standard errors [1]

Species and crown position	Leaf dry weight (grams)			N (% dry wt.)			P (% dry wt.)			K (% dry wt.)			Ca (% dry wt.)			Mg (% dry wt.)			Mn (% dry wt.)			Fe (ppm)		
	.05	.10	.15	.05	.10	.15	.005	.01	.05	.05	.10	.20	.05	.10	.15	.01	.02	.03	.01	.05	.10	4	8	12
Red oak:																								
Upper	13	4	2	15	4	2	9	2	1	5	2	1	5	2	1	3	1	1	9	1	1	20	5	3
Lower	16	4	2	17	5	2	8	2	1	6	2	1	5	2	1	4	1	1	10	1	1	17	5	2
White oak:																								
Upper	5	2	1	22	6	3	9	3	1	2	1	1	6	2	1	3	1	1	8	1	1	45	12	5
Lower	6	2	1	21	6	3	19	5	1	9	3	1	10	3	2	5	2	1	10	1	1	20	5	3
Chestnut oak:																								
Upper	7	2	1	12	3	2	14	4	1	4	1	1	3	1	1	2	1	1	5	1	1	20	5	3
Lower	11	3	2	11	3	2	11	3	1	7	2	1	6	2	1	6	2	1	8	1	1	32	8	4
Scarlet oak:																								
Upper	4	1	1	6	2	1	3	1	1	4	1	1	2	1	1	3	1	1	7	1	1	17	5	2
Lower	5	2	1	12	3	2	7	2	1	7	2	1	3	1	1	3	1	1	7	1	1	19	5	3

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[1] 0.95 confidence level, assuming samples of 25 leaves obtained from current-season growth located on periphery of crown; low-vigor branches excluded.

Table 4.—Number of samples required from individual trees for estimating nutrient content (mg/leaf) at selected standard errors[1]

Species and crown position	N			P			K			Ca			Mg			Mn			Fe		
	1	2	3	.05	.10	.20	.4	.8	1.0	.3	.6	1.0	.05	.10	.20	.05	.10	.20	.01	.03	.05
Red oak:																					
Upper	19	5	3	28	7	2	24	6	4	18	5	2	28	7	2	61	16	4	4	1	1
Lower	29	8	4	36	9	3	54	14	9	23	6	3	29	8	2	73	19	5	6	1	1
White oak:																					
Upper	9	3	1	12	3	1	4	1	1	4	1	1	4	1	1	9	3	1	4	1	1
Lower	12	3	2	19	5	2	5	2	1	9	3	1	9	3	1	11	3	1	1	1	1
Chestnut oak:																					
Upper	9	3	1	18	5	2	13	4	3	9	3	1	15	4	1	20	5	2	2	1	1
Lower	17	5	2	30	8	2	16	4	3	15	4	2	22	6	2	27	7	2	4	1	1
Scarlet oak:																					
Upper	5	2	1	6	2	1	3	1	1	3	1	1	6	2	1	20	5	2	2	1	1
Lower	7	2	1	10	3	1	6	2	1	5	2	1	6	2	1	15	4	1	2	1	1

[1] 0.95 confidence level, assuming samples of 25 leaves obtained from current-season growth located on periphery of crown; low-vigor branches excluded.

more difficult-to-reach branches in upper positions. However, only one or two additional branches in the lower crown need be sampled in most cases to achieve the same accuracy obtainable with foliage from upper locations.

Reasonable estimates of tree nutrition are possible if sampling is not limited to foliage located on only one branch. This study showed that a composite sample consisting of four 25-leaf subsamples collected during late August from well-distributed locations anywhere in the tree crown will usually be sufficient for estimating N to within ±0.10 percent N and P to within ±0.01 percent P. Also, a composite sample consisting of three 25 leaf subsamples obtained from separate branches in the lower crown or two in the upper crown will allow estimates to be within ±0.10 percent K, ±0.10 percent Ca, ±0.03 percent Mg, and ±0.1 grams for leaf weight in 95 cases out of 100. Closer estimates of tree nutrition require more intensive sampling (table 3).

Stand Variation

Tree-to-tree variation for leaf weight and foliar-nutrient composition was substantially greater than variation within individual trees. Generally, variation among individual trees of a single species was lowest for N and P, intermediate for K, and highest for leaf weight and the other cations. Tree-to-tree variability was greater for leaf weight and foliar content than it was for nutrient concentrations (appendix, tables 11 and 12).

The number of trees that should be sampled for estimating average stand nutrition varies with species and sampling position in the crown, and varies greatly among the different nutrients (tables 5 and 6). Data from our study show that samples from four trees growing on homogenous sites will generally be enough for estimating foliar N and P concentrations of the stand to within 10 percent of the mean. A much larger sample is necessary for estimating leaf weight, cation concentration, and nutrient content with the same precision.

There does not seem to be any superior sampling position for which nutrient variation remains consistently below other positions for all species. Samples obtained from the lower crown will serve as well as samples from the terminal and upper-crown positions and better than those from the interior.

From these results, we can recommend a suitable standardized sampling procedure for quantifying stand nutrition for upland oaks on homogenous sites. For each tree sampled, four composite samples of 25 leaves should be taken from current-season shoots from each of four well-distributed branches on the exterior part of the lower crown. A minimum of four trees should be sampled for red, white, chestnut, and scarlet oaks. Lower-crown foliage has the advantage of being easier, quicker, less expensive, and less dangerous to obtain. Standardizing the location from which foliar material is obtained will reduce variation and will improve the reliability of foliar-nutrient data for comparative purposes.

CONCLUSIONS

A study of foliar nutrient variation in a 60-year-old even-aged oak stand in West Virginia showed that:

- Samples obtained from lower crown positions satisfy sampling requirements as well as those from terminal and upper locations and better than those from interior positions for estimating tree and stand nutrition.
- Foliar-nutrient composition and leaf weight of individual trees are unaffected by the direction in which branches are oriented within the crown. This means that it is not necessary to restrict foliar sampling to a specific cardinal point.
- For comparative purposes, foliage to be analyzed for weight and K, Ca, and Mg concentrations should come from specific crown positions because these concentrations are dependent upon sampling location; samples for N, P, Mn, and Fe analyses may come from any crown position because concentrations of these nutrients are not position-dependent.
- Foliar-nutrient variation within trees is slightly less in the upper crown than in the lower crown, but for sampling purposes only one or two extra branches from the lower

Table 5.—Number of trees to sample for estimating foliar dry weight and nutrient concentrations (percent dry weight) to within a given percentage of the stand mean (5, 10, and 15 percent), by crown positions [1]

Species and crown position	Dry weight			N			P			K			Ca			Mg			Mn			Fe		
	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15
Red oak:																								
Terminal	81	21	9	8	2	1	4	1	1	25	7	3	39	10	5	45	12	5	33	9	4	26	7	3
Upper	124	31	14	5	1	1	5	1	1	21	5	2	42	10	5	51	13	6	19	5	2	18	5	2
Lower	106	27	12	4	1	1	7	2	1	22	6	3	33	8	4	40	10	5	27	7	3	29	7	3
Interior	56	15	7	3	1	1	6	2	1	21	6	3	58	15	7	30	8	4	56	14	7	62	16	7
White oak:																								
Terminal	137	35	16	8	2	1	13	4	2	37	10	5	92	23	11	25	7	3	170	43	19	90	23	10
Upper	160	40	18	7	2	1	12	3	1	27	7	3	59	15	7	74	18	8	120	30	13	104	26	12
Lower	100	25	11	10	3	1	13	3	2	67	17	7	54	14	6	46	12	5	115	29	13	112	28	13
Interior	66	17	8	6	2	1	8	2	1	44	11	5	41	11	5	49	13	6	114	29	13	150	38	17
Chestnut oak:																								
Terminal	49	13	6	10	3	1	35	9	4	10	3	2	53	14	6	72	18	8	74	19	9	59	15	7
Upper	54	14	6	6	2	1	29	7	3	9	2	1	41	10	5	66	17	7	47	12	5	31	8	3
Lower	14	4	2	7	2	1	35	9	4	11	3	1	74	19	8	40	10	5	74	19	8	29	7	3
Interior	130	33	15	9	3	1	19	5	3	42	11	5	57	15	7	50	13	6	77	20	9	48	12	6
Scarlet oak:																								
Terminal	46	12	6	13	4	2	19	5	3	33	9	4	44	11	5	107	27	12	58	15	7	89	23	10
Upper	53	13	6	10	3	1	11	3	1	38	9	4	41	10	5	99	25	11	34	9	4	51	13	6
Lower	60	15	7	8	2	1	9	2	1	34	9	4	47	12	5	52	13	6	58	14	6	31	8	4
Interior	20	5	3	12	3	2	8	2	1	105	27	12	45	12	5	59	15	7	68	17	8	35	9	4

[1] 0.95 confidence level, assuming that samples from individual trees will be a composite of: (1) 25 leaves for terminal or interior positions and (2) 25 leaves from each of 4 separate branches for upper or lower crown positions.

Table 6.—Number of trees to sample for estimating foliar nutrient content per leaf (mg/leaf) to within a given percentage of the stand mean (5, 10, and 15 percent) by crown positions[1]

Species and crown position	N			P			K			Ca			Mg			Mn			Fe		
	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15	.05	.10	.15
Red oak:																					
Terminal	59	15	7	85	22	10	111	28	13	197	50	22	150	38	17	98	25	11	158	40	18
Upper	108	27	12	135	34	15	154	39	18	242	61	27	211	53	24	100	25	12	206	52	23
Lower	125	32	14	139	35	16	135	34	15	180	45	20	120	30	14	120	30	14	200	50	23
Interior	50	13	6	71	18	8	94	24	11	151	38	17	81	21	9	91	23	11	148	37	17
White oak:																					
Terminal	173	44	20	135	34	15	225	57	25	308	77	35	213	54	24	438	110	49	219	55	25
Upper	223	56	25	172	43	19	217	55	25	230	58	26	231	58	26	339	85	38	213	54	24
Lower	127	32	15	107	27	12	129	33	15	163	41	19	159	40	18	294	74	33	174	44	20
Interior	90	23	10	84	21	10	113	29	13	157	40	18	119	30	14	305	77	34	334	84	38
Chestnut oak:																					
Terminal	59	15	7	86	22	10	58	15	7	62	16	7	156	39	18	70	18	8	85	22	10
Upper	52	13	6	84	21	10	80	20	9	58	15	7	130	33	15	68	17	8	86	22	10
Lower	15	4	2	43	11	5	25	7	3	50	13	6	51	13	6	43	11	5	29	7	4
Interior	138	35	16	150	38	17	151	38	17	349	88	39	174	44	20	305	77	34	186	47	21
Scarlet oak:																					
Terminal	84	21	10	85	22	10	37	10	5	80	20	9	197	50	22	89	23	10	186	47	21
Upper	54	14	6	56	14	7	64	16	8	74	19	9	112	28	13	52	13	6	179	45	20
Lower	67	17	8	62	16	7	98	25	11	109	28	13	65	17	8	89	23	10	125	32	14
Interior	42	11	5	28	7	4	85	22	10	44	11	5	97	25	11	54	14	6	49	13	6

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[1] 0.95 confidence level, assuming that samples from individual trees will be a composite of: (1) 25 leaves for terminal or interior positions and (2) 25 leaves from each of 4 separate branches for upper or lower crown positions.

crown need be sampled to offset this variation.

- Variability of nutrient concentrations within the crowns of individual trees is lowest for N and P, intermediate for the cations, and highest for leaf weight. Nutrient content is much more variable than concentration because of added variability from large differences in leaf weight.

- Variation of leaf weight and nutrient composition is much greater among trees of a given species than variation within individual trees.

- In this study, internal nutrient concentrations were generally highest for red oak, lowest for scarlet oak, and variable for white and chestnut oaks, indicating that foliage from more than one species should not be combined for nutrient analyses.

Since this work concerns only one homogenous site, it is important to recognize that further studies of this nature are necessary before any conclusive sampling guidelines for oaks can be formulated on a broader basis. The question whether lower-crown samples will satisfactorily show the effects of stand treatment—such as thinning, fertilization, and irrigation—remains unanswered.

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APPENDIX

Table 7.—Dry weight and nutrient concentration comparisions among species, by crown positions[1]

Crown position	Red oak	White oak	Chestnut oak	Scarlet oak	Remarks
LEAF DRY WEIGHT *(grams)*					
Terminal	0.86a	0.52b	0.63ab	0.52b	Red oak significantly higher than white and scarlet oaks. No significant difference among chestnut, white, and scarlet oaks.
Upper	.81a	.48b	.64ab	.52b	
Lower	.76a	.47b	.64ab	.49b	
Interior	.73a	.40c	.60ab	.48bc	
All	0.79a	0.47b	0.63ab	0.50b	
NITROGEN *(percent)*					
Terminal	2.52a	2.47a	2.48a	2.26a	Red, white, and chestnut oaks higher than scarlet oak.
Upper	2.52a	2.56a	2.45a	2.24b	
Lower	2.48a	2.54a	2.47a	2.16b	
Interior	2.48a	2.56a	2.42a	2.21b	
All	2.50a	2.53a	2.46a	2.22b	
PHOSPHORUS *(percent)*					
Terminal	0.14a	0.14a	0.14a	0.12b	Red, white, and chestnut oaks higher than scarlet oak.
Upper	.14ab	.15a	.14ab	.12b	
Lower	.13ab	.15c	.14bc	.12a	
Interior	.14ab	.17c	.14bc	.12a	
All	0.14ab	0.15c	0.14bc	0.12a	
POTASSIUM *(percent)*					
Terminal	1.02a	0.74b	0.91a	0.68b	Red and chestnut oaks significantly higher than white and scarlet oaks.
Upper	1.04a	.73b	.90a	.70b	
Lower	1.07a	.76b	.98a	.73b	
Interior	1.21a	.92b	1.16ab	.92b	
All	1.08a	0.79b	0.99a	0.76b	
CALCIUM *(percent)*					
Terminal	0.55a	0.42b	0.55a	0.42b	Red, white, and chestnut oaks highest; scarlet oak lowest.
Upper	.55a	.47a	.54a	.44b	
Lower	.60a	.58a	.61a	.47b	
Interior	.58a	.61ab	.62b	.44c	
All	0.57a	0.52a	0.58a	0.44b	
MAGNESIUM *(percent)*					
Terminal	0.13a	0.08b	0.11ab	0.09b	Red oak significantly higher than white and scarlet oaks; chestnut oak intermediate.
Upper	.13a	.09b	.11ab	.10b	
Lower	.14a	.10b	.13a	.10b	
Interior	.14a	.11ab	.13a	.10b	
All	0.14a	0.10b	0.12ab	0.10b	
MANGANESE *(percent)*					
Terminal	0.18a	0.10b	0.11b	0.16a	Red and scarlet oaks significantly higher than chestnut and white oaks.
Upper	.18a	.10b	.11b	.17a	
Lower	.18a	.11b	.12b	.16a	
Interior	.16a	.11b	.11b	.14a	
All	0.18a	0.10b	0.11b	0.16a	
IRON *(ppm)*					
Terminal	94a	79a	92a	89a	No significant change.
Upper	95a	82a	88a	87a	
Lower	99a	89a	94a	82a	
Interior	101a	97a	109a	83a	
All	97a	87a	96a	85a	

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[1] Terminal and interior values are the averages of 10 samples obtained from 10 different trees. Lower and upper values are the averages of 40 samples (4 samples from each of 10 different trees). Each individual sample contained 25 leaves. Values in each *ROW* followed by the same letter are not significantly different (Scheffé test, $P < .05$).

Table 8.—Nutrient content (mg/leaf) comparisons among species, by crown positions[1]

Crown position	Red oak	White oak	Chestnut oak	Scarlet oak	Remarks
NITROGEN					
Terminal	21.57a	13.00b	15.56b	11.77b	Red oak significantly higher than white and scarlet oaks. Little difference among chestnut, white, and scarlet oaks.
Upper	20.29a	12.40b	15.54ab	11.61b	
Lower	18.97a	12.08bc	15.84ab	10.69c	
Interior	18.12a	10.38b	14.52ab	10.50b	
All	19.74a	11.96b	15.36ab	11.14b	
PHOSPHORUS					
Terminal	1.17a	0.76b	0.86b	0.64b	
Upper	1.10a	.72b	.87ab	.64b	
Lower	1.02a	.72bc	.91ab	.58c	Same as nitrogen.
Interior	.99a	.67bc	.87ab	.59c	
All	1.07a	0.72b	0.88ab	0.61b	
POTASSIUM					
Terminal	8.80a	3.92bc	5.70b	3.51c	Red oak significantly higher than chestnut, scarlet, and white oaks. Chestnut oak generally higher than scarlet and white oaks.
Upper	8.45a	3.54b	5.62b	3.58b	
Lower	8.19a	3.59b	6.27a	3.62b	
Interior	8.89a	3.71b	6.96a	4.32b	
All	8.58a	3.69c	6.14b	3.76c	
CALCIUM					
Terminal	4.79a	2.21b	3.44ab	2.15b	
Upper	4.49a	2.27b	2.27b	3.43ab	Red oak generally higher than scarlet, chestnut, and white oaks.
Lower	4.56a	2.73c	2.33bc	3.85ab	
Interior	4.27a	2.50b	3.77a	3.77a	
All	4.53a	2.43b	2.95b	3.30b	
MAGNESIUM					
Terminal	1.09a	0.43b	0.68b	0.47b	Red oak significantly higher than chestnut, scarlet, and white oaks. Chestnut oak generally higher than scarlet and white oaks.
Upper	1.03a	.42b	.68b	.49b	
Lower	1.03a	.46b	.81a	.48b	
Interior	1.01a	.44b	.81a	.45b	
All	1.04a	0.44c	0.74b	0.47bc	
MANGANESE					
Terminal	1.55a	0.54b	0.69b	0.80b	Red oak significantly higher than chestnut, white, and scarlet oaks, but the latter 3 species were not significantly different.
Upper	1.45a	.51c	.69bc	.86b	
Lower	1.36a	.53b	.73b	.80b	
Interior	1.21a	.47b	.69b	.68b	
All	1.39a	0.51b	0.70b	0.78b	
IRON					
Terminal	0.082a	0.041b	0.057ab	0.046b	Red oak significantly higher than scarlet and white oaks, but not chestnut oak. Trends were for chestnut oak to be higher than scarlet and white oaks.
Upper	.078a	.039b	.055ab	.045b	
Lower	.079a	.042b	.060ab	.040b	
Interior	.067a	.040b	.065ab	.039c	
All	0.076a	0.040b	0.059ab	0.042b	

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[1] Terminal and interior values are the averages of 10 samples obtained from 10 different trees. Lower and upper values are the averages of 40 samples (4 samples from each of 10 different trees). Each individual sample contained 25 leaves. Values in each *ROW* followed by the same letter are not significantly different (Scheffé test, $P < .05$).

Table 9.—Pooled coefficients of variation for leaf dry weight and nutrient concentration (percent dry weight) within individual trees for upper and lower crowns of 4 species of upland oak

Species and crown position	Leaf weight	N	P	K	Ca	Mg	Mn	Fe
					Percent			
Red oak:								
Upper	10	4	4	5	8	6	10	9
Lower	11	4	4	5	8	5	11	12
White oak:								
Upper	10	4	4	4	11	8	24	22
Lower	11	4	6	8	12	10	24	24
Chestnut oak:								
Upper	7	2	2	6	7	6	15	12
Lower	10	4	5	7	9	8	19	11
Scarlet oak:								
Upper	9	3	5	4	4	5	13	16
Lower	12	3	5	6	7	5	17	12

Table 10.—Pooled coefficients of variation for nutrient content (mg/leaf) within individual trees for upper and lower crowns of 4 species of upland oak

Species and crown position	N	P	K	Ca	Mg	Mn	Fe
				Percent			
Red oak:							
Upper	10	11	10	12	11	12	10
Lower	12	13	14	13	12	14	13
White oak:							
Upper	10	10	10	11	12	13	17
Lower	12	13	13	15	13	15	10
Chestnut oak:							
Upper	9	10	9	11	12	14	11
Lower	12	13	11	13	14	16	14
Scarlet oak:							
Upper	8	8	7	9	11	12	12
Lower	12	12	12	12	12	10	16

Table 11.—Pooled coefficients of variation among individual trees for foliar dry weight and nutrient concentration (percent dry weight) by crown position for 4 upland oaks

Species and crown position	Leaf weight	N	P	K	Ca	Mg	Mn	Fe
	Percent							
Red oak:								
Terminal	20	6	4	11	14	15	12	11
Upper	24	5	5	11	14	16	10	9
Lower	23	4	6	10	13	14	11	12
Interior	16	4	5	10	17	12	16	17
White oak:								
Terminal	26	6	8	13	21	21	29	21
Upper	30	6	8	11	17	19	24	22
Lower	22	7	8	18	16	15	24	23
Interior	18	5	6	14	14	19	24	27
Chestnut oak:								
Terminal	15	8	13	7	16	19	19	17
Upper	16	6	12	6	14	18	15	12
Lower	8	6	13	7	19	14	19	12
Interior	25	6	10	14	17	16	19	15
Scarlet oak:								
Terminal	15	8	10	13	15	23	17	21
Upper	16	7	8	14	14	22	13	16
Lower	17	6	7	13	15	16	17	12
Interior	10	8	6	22	15	17	18	13

Table 12.—Pooled coefficients of variation among individual trees for nutrient content (mg/leaf) by crown position for 4 upland oaks

Species and crown position	N	P	K	Ca	Mg	Mn	Fe
				Percent			
Red oak:							
Terminal	17	20	23	31	27	22	28
Upper	23	26	27	34	32	22	32
Lower	25	26	26	30	24	24	31
Interior	16	19	21	27	20	21	27
White oak:							
Terminal	29	26	33	39	32	46	33
Upper	33	29	32	34	34	41	32
Lower	25	23	25	28	28	38	29
Interior	21	20	23	28	24	38	40
Chestnut oak:							
Terminal	17	20	17	17	28	18	20
Upper	16	20	20	17	25	18	20
Lower	8	14	11	16	16	14	12
Interior	26	27	27	41	29	38	30
Scarlet oak:							
Terminal	20	20	13	20	31	21	30
Upper	16	16	18	19	23	16	30
Lower	18	17	22	23	18	21	25
Interior	14	12	20	14	22	16	15

Auchmoody, L. R., and K. P. Hammack.
1975. **Foliar nutrient variation in four species of upland oaks.** NE. Forest Exp. Stn., Upper Darby, Pa.
16 p. (USDA For. Serv. Res. Pap. NE-331)

A study of 60-year-old red, white, chestnut, and scarlet oaks in West Virginia suggests that easier-to-reach foliage from the lower crown is well suited for nutrient sampling. Variability was evaluated from samples obtained from the terminal shoot, from each cardinal point in the upper and lower crown, and from the interior. Concentrations of K, Ca, and Mg were generally higher in the lower than in the upper crown, while N, P Mn, and Fe concentrations were unrelated to position. Tree-to-tree variation was approximately the same for all crown positions. A standard field sampling procedure is suggested.

160.21 : 176.1 *Quercus* spp.

KEY WORDS: Foliar sampling, leaf dry weight, foliar nutrient levels, oaks.

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UNEVEN-AGED MANAGEMENT OF NORTHERN HARDWOODS IN NEW ENGLAND

by William B. Leak and Stanley M. Filip

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F. BRYAN CLARK, STATION DIRECTOR

Cover Photo

An uneven-aged stand of northern hardwoods in New England. Sugar maple, yellow birch, and American beech make up most of the volume.

THE AUTHORS

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ABSTRACT

Three main aspects of uneven-aged management in northern hardwoods are discussed: (1) choice of cutting method, including selection, group selection, and patch selection; (2) control of yields, which involves the establishment of structural goals, the control of marking operations, and the prediction of allowable harvest; and (3) the transportation or removal of products—truck roads, skidroads, and harvesting precautions. Emphasis is on flexibility: the possibilities of applying a range of cutting methods and structural goals to conform to varied objectives and stand conditions.

UNEVEN-AGED MANAGEMENT OF NORTHERN HARDWOODS IN NEW ENGLAND

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UNEVEN-AGED MANAGEMENT implemented by the selection system of cutting, has been recommended for handling certain northern hardwood forests in New England. During the past 17 years, the Northeastern Forest Experiment Station has issued three summary papers that deal with aspects of the management of uneven-aged northern hardwoods *(Gilbert and Jensen 1958, Leak and others 1969, Filip 1973)*. However, most of this earlier work dealt with silvicultural aspects rather than the entire managerial job of growing the timber, controlling the yields, and removing the products through an uneven-aged system. Furthermore, the traditional approach to uneven-aged management — single-tree selection coupled with biologically based structural goals—can be broadened to better meet current needs.

Three main issues must be examined by a forest manager in deciding whether or how to adopt uneven-aged management. First, he must decide upon a harvest-cutting method based primarily upon regeneration objectives and cost considerations. Second, he must decide how to control the yields, which involves setting residual stand objectives, marking stands, and predicting future yields. Third, he must decide how the timber will be removed; and then he must develop a transportation plan suited to the harvesting equipment.

These three questions will be examined in depth in this paper, providing a basis for setting up an uneven-aged management program for northern hardwoods. Because each forest property is unique, methodology will be stressed. However, applicable data and examples will be given where possible. Material that is readily available in other summary bulletins or as common professional knowledge will not be presented.

CHOICE OF CUTTING METHOD

The choice of an appropriate cutting method depends upon an understanding of the underlying differences between even-aged and uneven-aged management. The basis of even-aged management is this: the forest is (or will be) composed of reasonably even-aged stands of sufficient acreage so that they can be surveyed (mapped) and relocated. Under even-aged management, the appropriate harvest cutting methods—clearcutting, shelterwood, and seed-tree—are those that create new even-aged stands of sufficient acreage. The minimum acreage to qualify as *sufficient* is unique to each property and is difficult to define. On large properties in the northern hardwood region of New England, the minimum size of a stand seems to lie between 10 and 40 acres.

In contrast, forests under uneven-aged management are split into recognizable and relocatable stands on some basis other than age class. The basis for stand differentiation can be forest type, site, logging conditions, or some combination of these factors; but we do not keep track of acreages by stand age class because it is infeasible to do so. The appropriate harvest cutting methods are those that attain growth, quality, and species objectives without producing even-aged stands large enough to be surveyed and scheduled for treatment. Traditionally, the selection system of cutting has been associated with uneven-aged management. But for practical application, three approaches—and possible combinations of two or more—should be considered.

Uneven-Aged Cutting Methods

Single-tree selection consists of removing individual trees that usually are isolated from one another *(Smith 1962, U.S. Forest Service 1973)*. The trees to be removed will include those that are (1) merchantable and ready to take because of poor future potential (slow growth, risk, poor quality potential), and may include (2) unmerchantable trees, including large culls, that should be cut or killed because they suppress better stems. The emphasis here is on the individual characteristics of the removal trees. If several removal trees happen to occur together, forming a small group, we're still practicing single-tree selection.

Under *group selection*, there is a conscious effort to remove trees in groups of a few to many trees *(Smith 1962, U.S. Forest Service 1973)*. The area occupied by the group usually is less than an acre, but could range up to several acres in large stands. However, the area would be smaller than the minimum feasible acreage for a single stand under even-aged management. This holds true because, the larger the acreage, the more efficient even-aged management is. The removal trees generally have the same characteristics as those described under single-tree selection—merchantable trees with poor future potential plus some culls.

But instead of complete emphasis on individual tree characteristics, the predominant characteristics of the *group* must be evaluated. Often, a few high-potential stems will be removed with the low-potential stems. This apparent loss in flexibility or efficiency must be offset by a gain in the groupwise application of the cutting: (1) the chance to uniformly release some established regeneration; (2) the creation of conditions for the establishment and development of some intermediate or intolerant species; or (3) the reduction of logging damage by taking trees in groups. Trees are individually examined and marked under typical group-selection practice.

A third possible approach in northern hardwood stands, sometimes associated with even-aged management, is *patch selection*. This is not a traditional cutting method, but there has been a fair amount of experimentation with this approach in northern hardwood types *(Jensen 1943)*. Patch selection is the removal of all trees down to a small fixed limit (commonly 2 inches) on areas from a fraction of an acre up to 1 or 2 acres in size. This method is analogous to clearcutting, but it is applied to acreages smaller than the minimum-sized even-aged stand. It differs from group selection in that all trees within the patch boundary are cut rather than a few adjacent, individually selected stems.

Under patch selection, the cutting is centered around a group of trees that generally qualify as removal trees. The boundaries of the area must be marked so that the whole patch can be cleared. However, the acreage and location of the patch generally are not made part of the permanent records. Patch selection is appropriate for the release of small established regeneration; but the method is most appropriate for the establishment of new regeneration.

Regeneration Related to Cutting Method

Single-tree selection in northern hardwoods favors tolerant species with a small proportion of intermediates. A point that has not been previously appreciated, however, is that the small openings produced by removing two or three trees result in as high a percentage of intermediate species as small patch-selection cuttings. However, patch selection provides for more intolerant species (table 1).

A more detailed examination indicates that the initial proportions of yellow birch and ash can be almost as high in small openings under the selection system as in heavily cut areas such as the liquidation (commercial clearcutting) and diameter-limit cuttings listed in table 2. The fairly high proportion of intermediates in the small openings larger than 0.01 acres probably resulted from the chance release

Table 1.—Species composition[1] based on the tallest commercial stem per milacre plot[2]

Cutting method	Tolerants	Intermediates	Intolerants
	Percent		
Single-tree selection	81-92	7-18	1
Selection openings .01 acre +	68-80	18-31	1-2
Small patches .1 to .6 acre	62-77	7-34	4-16

[1] Tolerants are beech, sugar maple, eastern hemlock, and red spruce; intermediates yellow birch, white ash, and red maple; intolerant paper birch.

[2] Leak and Wilson 1958, Leak 1959, and Marquis 1965.

of some young regeneration together with the establishment of some new stems right after cutting—partly because of increased scarification from logging disturbance. Indications are that a conscious effort toward group selection—even using small groups containing only a few trees—will produce a marked increase in the proportion of intermediates as compared to standard single-tree selection. Maintenance of this initial advantage in species composition will require repeated release, especially of the smaller groups, during successive cutting cycles.

Although degree of cutting and size of opening have an important influence on the proportions of tolerant, intermediate, and intolerant species, it is important to realize that site factors will influence the regeneration of individual species within tolerance groups. Efforts are now under way to correlate soils and species in New England forest stands, and some general relationships already are emerging *(Lanier 1974)*. Loose to firm soils derived from glacial till commonly support typical northern hardwoods. Glacial-till soils underlain at about 3 feet or less with a hardpan support a fairly rich species mixture of both softwoods and hardwoods—possibly because such areas exhibit such a wide range in drainage. Outwash soils—sands and gravels—often contain high proportions of red spruce and white pine where the drainage is good, and higher amounts of balsam-fir where the drainage is poorer.

Much more information is needed about species/soils relationships. Until such information is available, however, the successional tendencies of a stand can sometimes be determined by careful field examination, with particular emphasis on understory development following past disturbance from cutting or natural causes. It is important to realize that the effects of cutting method on regeneration may be limited by soil and site conditions.

Harvest Costs Related to Cutting Method

A complete cost-and-return analysis of the various uneven-aged management options will

Table 2.—Species composition by cutting method and canopy opening, based on tallest commercial stem per milacre plot. Regeneration 3 feet tall to 1.5 inches dbh 7½ years after cutting (Leak 1959).

Cutting method and residual basal area	Canopy opening, size	Beech	Sugar maple	Eastern hemlock	Red spruce	Yellow birch	White ash	Red maple	Paper birch
						Percent			
Liquidation: 38 square feet	All	26	17	9	3	16	16	7	6
Diameter-limit: 64 square feet	.01 acre +	32	13	19	6	19	1	3	7
	Less than .01 acre	40	6	38	12	2	1	1	—
Moderate selection: 83 square feet	.01 acre +	38	20	8	1	16	11	4	2
	Less than .01 acre	63	15	15	4	2	1	—	—
Light selection: 95 square feet	.01 acre +	39	11	26	4	11	7	—	2
	Less than .01 acre	50	11	26	8	1	4	—	—

Table 3.—Dollar costs per unit of product harvested on the Bartlett Experimental Forest, by cutting method (Filip 1967)

Cutting method	Costs	Compartment	Total acreage
	Dollars	*No.*	*Acres*
Selection	$17.63	11	423
Patch	17.78	4	120
Diameter-limit	15.30	2	80
Clearcutting	17.75	1	41

not be attempted in this paper. However, it is important to make some evaluation of the efficiency of the various cutting methods, and the most logical way is to use costs per unit volume harvested.

Dollar costs per cunit (100 cubic feet) of product harvested were determined for cutting operations on 30- to 40-acre compartments on the Bartlett Experimental Forest *(Filip 1967)* (table 3). Results show almost identical costs per cunit for selection, patch, and clearcutting. Diameter-limit cutting down to a 13.0-inch limit (and a 7.0-inch limit on paper birch) cost less, no doubt because of the large size of material removed.

It is important to realize that these costs include all of the cutting and skidding phases. They do not include costs of truck-road construction because nearly all compartments were located near available truck roads. The costs do not include nor reflect the efficiency of certain managerial jobs such as tree-marking. Furthermore, on patch-selection areas, some additional cost or reduced stumpage rate might be required to cover the felling of unmerchantable stems.

Summary of Cutting Methods

Among the three cutting methods proposed —single-tree selection, group selection, and patch selection—there are no great differences in harvest-cutting costs. Apparently the choice of method depends upon species objectives and stand conditions.

To reproduce beech, sugar maple, or eastern hemlock, the single-tree selection method will work; but keep in mind that site conditions may determine the relative abundance of these three species. Single-tree selection provides maximum flexibility in choosing trees to take or leave, but does not provide much opportunity to manipulate understory development.

Where a well-established understory of desirable species (tolerants or intermediates) exists under a mature clump of overstory trees, group selection is the natural choice. The mature trees should be marked, together with any immature but merchantable trees that would be left isolated by the cutting. The size of the group depends upon the stand conditions, but normally it could range from two to three trees up to nearly an acre.

Where a low-potential group of trees is underlain by a definitely undesirable understory—weed trees, for example—or a sparse understory, patch selection would be a reasonable option because it provides the best opportunity for new regeneration with a fairly high proportion of intermediate and intolerant species. The patch borders should be marked so that everything within the patch will be harvested or felled down to a minimum diameter of not less than 2 inches. Some investment probably will be required to finance the cutting of unmerchantable trees; so patch selection should not be undertaken without a clear objective in mind. Patches generally will be less than 1 acre in size.

Ideally, a stand should be marked with a combination of cutting methods. Group or patch selection will often be chosen to produce an assortment of valuable species. However, the areas between groups or patches definitely should be marked for single-tree selection so that poor-risk trees can be salvaged.

CONTROL OF YIELDS

Yields under uneven-aged management are regulated through control of the growing stock —so-called volume control. For each stand or compartment, a residual stand structure (after cutting) must be set in terms of numbers of trees by diameter class, which determines basal area and volume. A marking procedure must be established so that a stand can periodically be marked back to the residual structure with some degree of accuracy. The difference between current structure and residual structure is the current yield of the stand. And, finally, growth must be projected several years (the cutting cycle) into the future to determine future structure. The difference between future structure and residual structure is the projected allowable harvest for that stand. Summation of allowable harvest by projected harvest dates for all stands or compartments in the forest produces an allowable harvest schedule for the forest.

Stand Structure Guides

The establishment of an appropriate residual structure for a stand is perhaps the most critical step in the regulation process because it has a very important bearing on the efficiency and productivity of uneven-aged management.

To allow for continuous yields, numbers of trees over dbh class must follow something approaching a reverse-J-shaped form. However, the exact form of the diameter distribution will vary depending upon regeneration, mortality, and cutting rates. A well-known theory of population dynamics indicates that any population subject to a consistent schedule of birth and death rates (including removals) will develop a stable (constant-shaped) age distribution curve.

When that population reaches a point where regeneration equals losses, the age distribution becomes stationary or constant *(Keyfitz 1968)*. Simulation work with northern hardwood stands *(Adams and Ek 1974)* illustrates how this principle may apply in practice to uneven-aged stands: constant or sustainable size (rather than age) distributions were derived for a range of residual basal areas and harvest options, some based on cutting through only the upper (sawlog) end of the diameter distribution. Apparently, sustained production from uneven-aged stands can be obtained by cutting through all or only part of the diameter distribution, provided that adequate regeneration is obtained to sustain the distribution. The decision on cutting policy would depend upon a careful analysis of the economics and markets involved. The appropriate residual stand structure would vary for each harvesting option.

In developing structural guidelines, we should not plan to keep in the residual stand trees that are well beyond their financial maturity. Growing hardwoods to very large sizes is not economical in stands devoted primarily to timber production.

Developing guidelines for the lower end of the structure is problematical. On the one hand, it might seem reasonable to maintain small numbers of 6- and 8-inch trees so that only a minimum volume of residual growing stock is in unmerchantable trees. However, northern hardwood stands have high regenerative potential. In cut stands, there is a tendency for the numbers of smaller stems to increase rapidly. So, the maintenance of small numbers of unmerchantable stems requires a commitment to cultural or marginal work in the smaller sizes.

Cultural work in understory trees generally is less beneficial to the residual stand than cultural work in the overstory. In typical uneven-aged stands maintained by single-tree selection, the 6- to 8-inch and smaller trees tend to be in the understory. However, where group or patch selection is practiced, there are better possibilities for cultural work in the areas of essentially even-aged young growth. So the feasibility of maintaining smaller-than-natural numbers of marginal or unmerchantable stems depends upon a commitment to cultural work which, in turn, is made more feasible by the maintenance of a group- or patch-wise distribution of size classes.

The concept of q *(Meyer 1952)*—the quotient between numbers of trees in successive 2-inch dbh classes—has traditionally been used to define stand structure for uneven-aged management. As discussed earlier, population theory and simulated results *(Adams and Ek 1974)* indicate that optimum residual structure may not follow the q distribution very well. However, when used with flexibility, q still remains as the best general method for defining residual structural goals.

Past recommendations indicate that northern hardwoods become financially mature at not larger than 20 to 22 inches dbh—often smaller—and that optimum residual stocking lies somewhere between 70 and 80 square feet

Table 4.—Residual stand structures designed for 70 square feet of residual basal area per acre up through the 20-inch class, and between 70 and 80 square feet up through the 22-inch class

Dbh class (inches)	q = 1.3		q = 1.4		q = 1.5		q = 1.6		q = 1.7		q = 1.8		q = 1.9		q = 2.0	
	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area
	No.	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*
6	26.8	5.25	35.3	6.91	44.2	8.67	53.8	10.55	63.5	12.45	73.2	14.34	82.8	16.22	92.0	18.04
8	20.7	7.22	25.2	8.78	29.5	10.30	33.6	11.73	37.3	13.03	40.6	14.18	43.6	15.20	46.0	16.06
10	15.9	8.67	17.9	9.78	19.7	10.72	21.0	11.45	22.0	11.98	22.6	12.31	22.9	12.49	23.0	12.54
12	12.2	9.61	12.8	10.05	13.1	10.30	13.1	10.31	12.9	10.14	12.5	9.84	12.1	9.47	11.5	9.03
14	9.4	10.03	9.1	9.78	8.7	9.35	8.2	8.77	7.6	8.13	7.0	7.45	6.4	6.79	5.8	6.14
16	7.2	10.08	6.6	9.15	5.8	8.13	5.1	7.15	4.5	6.24	3.9	5.41	3.3	4.67	2.9	4.01
18	5.6	9.82	4.7	8.25	3.9	6.86	3.2	5.67	2.6	4.64	2.2	3.80	1.8	3.11	1.4	2.54
20	4.3	9.31	3.3	7.28	2.6	5.64	2.0	4.36	1.5	3.37	1.2	2.61	.9	2.02	.7	1.57
22	3.3	8.67	2.4	6.29	1.7	4.56	1.2	3.30	.9	2.40	.7	1.76	.5	1.29	.4	.95
Total	105.4	78.7	117.3	76.3	129.2	74.5	141.2	73.3	152.8	72.4	163.9	71.7	174.3	71.3	183.7	70.9

Table 5.—Examples of the basal areas and volumes removed per acre for two residual stocking alternatives

Dbh class (inches)	Initial stand		q = 2.0				q = 1.6			
			Residual		Cut		Residual		Cut	
	Trees	Basal area	Trees	Basal area	Basal area	Volume	Trees	Basal area	Basal area	Volume
	No.	*Sq. ft.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Bd. ft.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Bd. ft.*
6	94.7	18.56	92.0	18.04	0.52	—	73.2	14.34	4.22	—
8	53.9	18.81	46.0	16.06	2.75	—	40.6	14.18	4.63	—
10	27.0	14.72	23.0	12.54	2.18	—	27.6	12.31	2.41	—
12	27.2	21.35	11.5	9.03	12.32	1,539	12.5	9.84	11.51	1,441
14	16.1	17.21	5.8	6.15	11.06	1,638	7.0	7.45	9.76	1,447
16	7.2	10.05	2.9	4.01	6.04	968	3.9	5.41	4.64	742
18	4.9	8.66	1.4	2.54	6.12	1,054	2.2	3.80	4.86	813
20	1.6	3.49	.7	1.57	1.92	339	1.2	2.61	.88	151
22	.5	1.43	.4	.95	.48	47	.7	1.76	—	—
All	233.1	114.3	183.7	70.9	43.4	5,585	163.9	71.7	42.9	4,594

of basal area per acre *(Leak and others 1969)*. Table 4 gives minimum residual structural goals for a range in q. As q increases, the number and proportion of small trees increase. The acceptance of a 20-inch upper limit provides for 70 square feet of residual basal area while a 22-inch upper limit provides for a little more. These suggested structures should be used flexibly. In some cases, one q might be applied to the sawtimber sizes, and another q might be used to guide the marking in the poletimber sizes. Some of the possibilities are best illustrated by example.

In table 5, figures are given for an initial stand that averages 114.3 square feet of basal area and therefore can support a harvest cutting. This is an actual 40-acre stand on the Bartlett Experiment Forest, about 100 years old. Although the stand structure follows a fairly typical reverse-J form, the trees actually occur in a patch-like arrangement due to patch cuttings several years earlier.

One option in marking this stand would be to assume that little or no work will be done in the 8-inch class and smaller. Although 6- and 8-inch trees contain some merchantable material, the harvesting of these sizes would be a marginal operation, more like a cultural treatment than a harvesting operation. Under this option, the appropriate residual structure is one that will concentrate the cutting in the larger sizes, 10 inches and over. The appropriate choice is q = 2.0. Notice that a residual q of 1.9 (table 4) or less would require more and more cultural work in the 6- and 8-inch classes. By subtracting the residual goal for q = 2.0 from the initial stand and using local volume tables, and basal area and volume to be removed in each dbh class is easily determined. Note that the goal can be met by removing very little from the 6- and 8-inch classes (table 5).

Under more intensive management, some marginal or cultural work in the 6- and 8-inch classes and smaller might be contemplated. The decision to invest in such work would be based upon site and quality considerations, and also upon an evaluation of whether these smaller sizes did in fact occur in group- or patch-wise arrangements. Under this option, a residual structure of q = 1.8 would work well; q = 1.9 could also be considered. However, low q values of 1.4 or 1.5 could not be considered for an immediate goal. Such low q distributions would not only require heavy treatment in the small sizes—which might or might not be justified: they simply could not be met in the larger sizes because of a lack of trees.

Under q = 1.8, basal areas and volumes to remove are calculated as before (table 5). Under this option, more work would be done in the small sizes, and more volume would be left in the larger sizes. Current volume harvested would be less than under the first option of q = 2.0.

A third option might be to apply a q = 2.0 to the poletimber, which would entail very little work in these small sizes, and a q of perhaps 1.7 to the sawtimber sizes. This option would provide for a somewhat heavier residual stocking in the sawtimber sizes than the previous options of q = 1.8 or 2.0. Another possibility would be to use a proportionate rule such as the removal of 1/3 or 2/5 of the sawtimber-size trees plus any poletimber removals that could be well justified as a cultural measure. The consistent removal of a specific proportion of trees, carefully defined for each dbh class on the basis of financial return and cultural benefit, is the approach that probably comes closest to the concept of a constant mortality/removal schedule as found in population dynamics theory.

We do not yet know enough about stand response and structural goals to exactly predict future courses of action in this stand. Depending upon stand response and markets, the manager might be able to work toward a higher and higher proportion of sawtimber. It is quite possible that some harvesting options might lead to temporary excesses in certain size classes. However, this possibility does not necessarily dictate heavy cultural work in small trees. A more feasible approach might be to wait and see, and then harvest any excesses as merchantable small sawtimber. As experience develops in each stand, a constant residual structure should gradually evolve in which yields and level of cultural investment appear optimum.

Under single-tree selection, residual stocking probably should be set a little higher than under group and patch selection. Furthermore, because of logging damage and other possible losses, some cushion should be left over and above the guidelines given in table 4. In general, then, these suggested structures are minimums.

Marking

Once the residual structural goal has been set, the next job is to mark to that goal in the field. The structural goal is set primarily to meet regulation objectives. In marking, good silvicultural practice also must be applied. (See *Leak and others 1969* for suggestions on types of trees to mark for harvest and cultural operations). Sometimes, a structural goal cannot be met because of silvicultural conditions. This doesn't do any great harm because, in any given stand, good silviculture is more important than strict adherance to a structural guide. However, no marking should be done without a structural guide regardless of whether the cutting method is single-tree selection, group selection, patch selection, or some combination of these.

Experienced markers can do an acceptable job without any formal controls on the marking operation. They proceed with nothing more than a structural goal, an estimate of numbers of trees or basal area to remove by size class, and an occasional check with a prism. However, for most foresters, marking to a given structure could be a difficult task, so some type of formalized procedure would seem necessary. This is especially important in stands where group or patch selection is practiced because marking control tends to be more difficult in patchy stands.

Most marking jobs begin with an estimate of the initial stand and, of course, a structural goal. These figures provide two useful marking tools: estimates of basal area and numbers of trees to remove per dbh class per acre. For example, looking back at table 5 under the first structural goal, we see that about 43 square feet of basal area can be removed per acre, that the 12- and 14-inch classes will be marked most heavily, and that the 16- and 18-inch classes will receive the second heaviest marking. However, under the procedure presented here, marking can be controlled to some extent even without these prior estimates of basal areas and numbers to be removed.

The marking crew should consist of a tallyman, who is responsible for controlling the marking job, and about two markers. Marking is done by eye, concentrating upon the silvicultural needs of the stand. Periodically, the tallyman will take a 10-factor prism estimate of the *residual stand after marking*. Trees will be recorded by 2-inch dbh classes on a standard cumulative tally sheet. Very little time is required to take these plots, so it seems quite feasible to take two or three plots per hour on a fixed time schedule. It is very important to take the plots systematically regardless of stand conditions, presence of patches or groups, etc.

Periodically, the prism tally is converted to trees per acre, and the average prism estimate is compared to the structural goal:

D.b.h. (inches)	*Goal (No. trees)*	*Residual stand (prism) (No. trees)*
6	44	28
8	30	25
10	20	22
12	13	17
14	9	6
16	6	6
18	4	4
20	3	3
22	2	—

In this hypothetical case, the obvious trend has been to mark too many 6-, 8-, and 14-inch trees; marking trees 16 inches dbh and larger is all right except for some apparent overmarking in the 22-inch class. The tallyman should discuss these trends with the markers so that an attempt will be made to bend the actual residual back toward the goal. The next check on marking practice will indicate whether progress is being made or whether additional changes are needed.

By this process of successive checks and revision, the average per-acre residual should come fairly close to the goal. Although this approach results in some degree of unevenness in marking procedure, remember that the primary purpose of structural control is to regulate yields from the stand rather than to ensure uniform silvicultural treatment. In reasonably homogeneous stands, successive prism estimates of the residual stand after marking converge fairly rapidly to a constant structure. Notice in table 6 that the average prism tally had settled down to a fairly constant structure by the time nine plots had been taken.

Table 6.—Successive prism estimates of the residual stand per acre after marking a 37-acre northern hardwood stand

Dbh class (inches)	Number of prism plots			
	5	9	15	21
	No. trees	*No. trees*	*No. trees*	*No. trees*
6	41	28	24	29
8	11	25	25	25
10	22	22	24	24
12	25	17	18	16
14	9	6	8	7
16	3	6	7	8
18	5	4	4	5
20	4	3	2	2
22	—	—	—	—
24	—	—	.2	.1

Some markers prefer to combine 2-inch diameter classes into 4-inch classes for purposes of marking control. Reducing the number of classes simplifies the marking procedure.

Cultural needs in groups or patches of young growth, and cull removal, probably should be marked during the regular marking operation. Trees smaller than 6 inches can be marked, although it does not seem feasible under current conditions to keep records on numbers of residual stems smaller than 6 inches, especially by prism methods. A complete tally of marked unmerchantable stems should be taken as a basis for estimating cultural costs. The actual cultural operation might be performed during the logging job or later as a separate operation.

Allowable Harvest Projection

Under uneven-aged management of northern hardwoods, the projection of allowable harvest is simple in concept. Begin with the residual structure after a marking or cutting operation. The prism tally used for the marking operation can meet this need, or a more detailed post-logging inventory that accounts for marked-but-not-cut, cut-but-not-marked, and damaged trees. Increases in basal area and numbers of trees are projected by dbh classes over the next cutting cycle—recommended as 12 to 20 years *(Leak and others 1969)*. And the projected allowable harvest is determined as the difference between the projected structure and a specified residual goal (table 4). This residual structural goal need not be the same as the previous goal; in many cases, it may be possible to work toward a smaller q (higher percentage of sawtimber) in successive cycles.

An example of allowable harvest projection is given in table 7, using actual basal-area changes from a compartment on the Bartlett Experimental Forest. Allowable harvest for a forest would be determined by following this procedure for each stand or compartment and then summing up the yields. Irregularities from year to year in total forest yields could be smoothed by small adjustments in the cutting cycles.

The weak point in this procedure is the lack of data for projecting growth. The ideal basis for projection is remeasurement of plots on each compartment. Measured growth following treatment is used to project stand development following a second treatment. Stand-table projection, based on diameter-growth analysis, is uncertain because of the difficulty of predicting mortality.

However, if remeasurement data for a specific stand are not available, published or reported information on growth rates may prove useful in making tentative growth predictions. Annual basal-area production in trees 5 inches dbh and larger tends to vary with stand density. This can be shown by examining reported production rates for stands of 60 to 100 square feet of residual basal area as compared to stands having over 100 square feet:

Annual basal-area production, in square feet

In stands of 60 to 100 square feet	*In stands of 100+ square feet*
2.3 *(Leak 1961)*	1.9 *(Filip et al. 1960)*
2.1 *(Leak 1961)*	0.6 *(Filip et al. 1960)*
2.3 *(Blum 1960)*	1.2 *(Leak 1961)*
2.0 *(Blum 1960)*	0.3 *(Gilbert and others 1955)*
1.9 *(Blum 1960)*	
1.9 *(Filip 1972)*	
1.1 *(Gilbert and others 1955)*	

The variation in rates in the 60- to 100-square-foot class must be due partly to site differences. As yet, however, we have no specific way to evaluate sites in uneven-aged northern hardwood stands. The lowest rate in this class (1.1 square feet) was the result of mortality caused by beech-bark disease. Under the 100+ class, the lowest rates of 0.3 and 0.6 square feet represent those stands that are nearing the maximum basal areas attainable

Table 7.—Example of stand allowable harvest calculation for a 19-year cutting cycle, using q=1.5 as a future goal, per-acre (Filip 1972)

Dbh class (inches)	Current stand		Future stand		Future goal		Future cut			
	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Volumes	
	Sq. ft.	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Cu. ft.*	*Bd. ft.*
6	9	44	11	56	9	44	2	12	—	—
8	10	29	12	34	10	29	2	5	—	—
10	13	24	16	29	11	20	5	9	112	—
12	11	14	18	23	10	13	8	10	202	980
14	13	12	17	16	9	9	8	7	183	1,113
16	9	6	15	11	8	6	7	5	186	1,125
18	4	2	10	6	7	4	3	2	93	602
20	2	1	4	2	6	3	—	—	—	—
22	2	1	4	1	5	2	—	—	—	—
24	2	1	4	1	—	—	4	1	81	569
Total	75	134	111	179	75	130	39	51	857	4,389

by northern hardwoods of 120 to 130 square feet of basal area; at these high densities, natural mortality is high.

In general, northern hardwood stands that have been cut to residual basal areas of 70 to 80 square feet should produce 2.0 to 2.3 square feet of basal area per acre annually over the next 10- to 20-year period, unless complications arise from insect-disease attack.

The next important consideration in projecting growth is how to distribute anticipated basal-area production between poletimber and sawtimber. The distribution of growth depends upon stand density and stand structure. In table 8, notice that stands having more than 100 square feet basal area produce 80 to 100 percent of their growth in sawtimber trees, 10.5 or 11.0 inches dbh or larger, regardless of structural differences in percentage of sawtimber.

In stands of 60 to 100 square feet of basal area and 25 to 50 percent of sawtimber (q = 1.7+), roughly 50 to 65 percent of the growth is in sawtimber trees (table 8). These stands with high q and low percentage of sawtimber are typical of second-growth even-aged stands 80 to 100 years old. Under 50 to 70 percent sawtimber, represented by a q of 1.4 to 1.6, the percentage of basal area growth in sawtimber trees ranges from about 60 to 80 percent. Note that the percentage of growth in sawtimber trees appears to increase only moderately as the percentage of sawtimber increases to 70 to 90 percent. Apparently a q of 1.4 to 1.6 will result in only a little less sawtimber production than a q of 1.3 or less.

Table 8.—Approximate percentage of basal growth in sawtimber trees (10.5 or 11.0 inches dbh and larger) by basal area per acre and percentage of sawtimber[1]

Percent sawtimber	Basal area in square feet per acre	
	60 to 100	100+
	Percent	*Percent*
25-50 (q = 1.7+)	50-70	100
50-70 (q = 1.4-1.6)	60-80	95-100
70-90 (q = 1.3 and less)	70-85	80+

[1] Based on summarization and rounding-off of data reported by Blum *(1960)*, Filip and others *(1960)*, Filip *(1972)*, Leak *(1961)*, and unpublished data.

An example of a projection of allowable harvest based on reported growth figures is given in table 9 for the same stand tabulated in table 7. An annual basal area growth of 2.0 square feet per acre is assumed. Since the initial stand contains 57 percent sawtimber, we assumed that the percentage of growth in sawtimber trees would lie between 60 to 80 percent, or about 70 percent (table 8). The growth was then distributed among dbh classes within sawtimber and poletimber in proportion to the initial basal area per class. Then the calculations follow those in table 7. In this particular case, the estimated allowable harvest based on reported growth figures (table 9) came out roughly the same as allowable harvest based on actual compartment growth (table 7).

TRANSPORTATION

One of the most important obstacles to economical uneven-aged management is the cost of developing and maintaining an adequate transportation system. In terms of cost, the truck-road system is the most important consideration and will be discussed first. Following that, some suggestions will be given on the skidding and harvesting phases.

Truck Roads

Under even-aged management, based on clearcutting, the cost of building truck roads to the landing or landings can be spread over the entire merchantable volume found on the cutting area. After the clearcutting, no truck road access may be needed until the first commercial thinnings are made perhaps 60 years later.

Uneven-aged management in northern hardwoods requires truck-road access every 12 to 20 years (the cutting cycle) to landings located within skidding distance of all sections of the stand or compartment. Because of frequent use, the only feasible approach in uneven-aged management is to set up permanent truck roads to service all areas of the stand or compartment. These roads need not be maintained

Table 9.—Example of allowable harvest over a 19-year cutting cycle based on reported growth figures: 2.0 square feet per acre per year: 70 percent of growth in sawtimber trees

Dbh class (inches)	Current stand		Basal-area growth		Future stand		Future goal		Future cut			
	Basal area	Trees	1 yr.	19 yrs.	Basal area	Trees	Basal area	Trees	Basal area	Trees	Volumes	
	Sq. ft.	*No.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Cu. ft.*	*Bd. ft.*
6	9	44	0.169	3.21	12.2	62	9	44	3.2	18	—	—
8	10	29	.187	3.55	13.6	39	10	29	3.6	10	—	—
10	13	24	.244	4.64	17.6	32	11	20	6.6	12	150	—
Subtotal	—	—	.600	—	—	—	—	—	—	—	—	—
12	11	14	.359	6.82	17.8	23	10	13	7.8	10	202	980
14	13	12	.423	8.04	21.0	20	9	9	12.0	11	287	1,749
16	9	6	.293	5.57	14.6	10	8	6	6.6	4	149	900
18	4	2	.130	2.47	6.5	4	7	4	—	—	—	—
20	2	1	.065	1.24	3.2	1	6	3	—	—	—	—
22	2	1	.065	1.24	3.2	1	5	2	—	—	—	—
24	2	1	.065	1.24	3.2	1	—	—	3.2	1	81	569
Subtotal	—	—	1.400	—	—	—	—	—	—	—	—	—
Total	75	139	2.000	38.02	112.9	193	75	130	43.0	66	869	4,198

annually, but they will need to be opened up and repaired as necessary for each cut.

The number and location of truck roads depends upon the maximum feasible skidding distance, which in turn depends upon current and future equipment. Past experience on the Bartlett Experiment Forest with tractor-arch combinations indicates that skidding distances up to 1,500 feet are reasonable *(Filip 1967)*. With recent and expected advances in equipment, perhaps this figure could be increased somewhat. But using 1,500 feet as an example, we think that the truck roads could be located so that each serves a strip about 3,000 feet wide. On this basis, a mile of truck road could service about 350 to 400 acres of the stand. On the first entry into the stand, the primary financial consideration is to determine to what extent stumpage returns from 350 to 400 acres will cover the costs of building 1 mile of a certain standard of road. On reentries into the stand, the same question would be applied to the costs of reopening and repairing the permanent road.

For example: the 5.5 Mbf of sawtimber to be harvested per acre from the stand represented in table 5 might bring a stumpage value of $40 per M, or $220 per acre. This amounts to $88,000 to balance against the cost of building or reopening 1 mile of road.

Skidroads

Two types of skidroads must be considered. The main skidroads are constructed by bulldozing. Most of the timber from a given section of the sale comes down the main skidroad. The secondary skidroads commonly consist of natural paths or corridors in the woods through which tree lengths are skidded and winched to the main skidroad.

The main skidroads should be laid out, following the usual precautions, in advance of the logging operation. These roads should provide ready access to the marked timber, especially to concentrations of timber marked in groups or patches. Grades should be gradual —less than 20 percent in most cases—to reduce erosion hazards. Uphill skidding should be avoided, although some uphill winching is feasible. Since the skidding operation may seriously damage up to 5 percent of the residual stand *(Nyland and Gabriel 1972)*, special precautions should be taken to minimize such damage. The skidroads should be as straight as possible, because much of the serious damage occurs on sharp turns. Where a turn or switchback is required, it should be located where the margins of the turn are bordered by mature trees that will be removed during the sale or left indefinitely. Furthermore, the roads should be reasonably wide—depending upon equipment and size of timber to be removed—to help eliminate damage to border trees.

The number and spacing of main skidroads depends heavily upon terrain and equipment. Some past experience indicates that skidding-winching distances of 300 to 400 feet from the main skidroad are reasonable *(Trimble and Barr 1960)*. Since uphill skidding is not very feasible, this means that main skidroads should not be spaced more than about 500 feet apart.

In most cases, the main skidroads will be used again and again for successive cuttings. However, for each cutting, some rerouting will be necessary to avoid patches of good regeneration and to provide good access to concentrations of marked timber.

The secondary skidroads, which generally require no bulldozing, are located as needed by the skidder operators. These skidroads are used to move small amounts of timber to the main skidroads, and are not subject to heavy traffic.

Harvesting

Felling operations cause more damage to the residual stand—up to 12 percent—than any other operation *(Nyland and Gabriel 1972)*. Special efforts should be made to prevent this kind of injury.

The use of group and patch selection should help to prevent damage to the residual stand because trees can be felled toward the center of the opening rather than into the residual stand. There is some precedence for this point of view, although comparative data are not yet available *(Smith 1962)*. In fact, one of the criteria in selecting and marking groups should be the control of logging damage. For example, if a mature tree cannot be felled without damaging several adjacent trees, the entire group probably should be taken.

Table 10.—Numbers of stems per acre of valuable species (paper birch, yellow birch, sugar maple, and white ash) in 3-year-old patch cuttings, by seedbed condition and stand age class (Marquis 1965)

Stand age class	Skid-road	Dis-turbed	Undis-turbed	Slash-pile
	M stems	*M stems*	*M stems*	*M stems*
Old-growth	161.3	76.6	47.7	7.5
Second-growth	174.2	84.9	35.6	11.0

The only other available means for controlling logging damage is through careful supervision of the logging job and repeated instruction of the fellers. To our knowledge, specifications on maximum acceptable logging damage are not generally incorporated into sales contracts; this possibility should be explored more thoroughly.

A second aspect of harvesting that is important to the landowner is the handling of slash. Obviously, heavy slash can be unsightly, can contribute to fire hazard in some cases, and can reflect less-than-optimum utilization. But a less-well-known effect of slash is its inhibitory effect on northern hardwood regeneration. In small patch cuttings, seedlings of desirable species are far fewer under slash than in any other seedbed condition (table 10). Trends toward whole-tree logging and chipping may help eliminate this problem. However, on standard sales, where the tops are left in the woods, the best solution to the slash problem appears to be lopping the tops close to the ground. Attempts to drag the tops into the adjacent residual stand probably would add to the logging damage.

Summary

The three main concerns in setting up an uneven-aged management program in northern hardwoods in New England are (1) choice of cutting method, (2) control of yields, and (3) removal of products.

Group and patch selection are encouraged to provide a good species mix. However, single-tree selection should be applied between groups and patches to remove poor-risk trees.

Alternative stand structures are defined in terms of q, the average quotient between numbers of trees in successive dbh classes. A structure should be chosen that provides for a reasonable cut of sawtimber-size stems and allows for a predetermined level of cultural or marginal work in the smaller sizes. To meet the chosen structure, a procedure is described for controlling the marking by repeated prism estimates of the residual stand, periodic comparisons of residual vs. goal, and subsequent adjustments in marking practice. Allowable harvest is estimated by projecting stand development over the cutting cycle, based on plot remeasurement or the application of reported information on basal-area growth and the distribution of growth between poletimber and sawtimber.

Truck roads should be permanently and carefully located in uneven-aged stands or compartments. The spacing of the truck roads depends upon estimated feasible skidding distances. And the cost of the truck roads should be weighed against the estimated stumpage returns from the acreage of the stand serviced by the road system. Main skidroads (requiring bulldozing) also should be laid out in advance of the sale. They should be fairly straight, with mature buffer trees on the turns to minimize damage to the residual stand. Felling damage probably can be controlled to some extent by cutting trees in groups and patches. Since heavy slash inhibits northern hardwood regeneration and is undesirable for other reasons, slash treatment in areas under group or patch selection should consist of lopping the material so that it lies close to the ground.

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Three main aspects of uneven-aged management in northern hardwoods are discussed: (1) choice of cutting method, including selection, group selection, and patch selection; (2) control of yields, which involves the establishment of structural goals, the control of marking operations, and the prediction of allowable harvest; and (3) the transportation or removal of products—truck roads, skidroads, and harvesting precautions.

62 : 221.4 : 228.6 : 176.1 - - (74)

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HARDWOOD TREE GRADES FOR FACTORY LUMBER

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HARDWOOD TREE GRADES FOR FACTORY LUMBER

ABSTRACT

The Forest Service hardwood tree grades for factory lumber are described, and lumber grade yields for 11 species are presented. The yields, expressed in board feet, are based on equations in which dbh^2 and merchantable height were used as independent variables. Actual board-foot volumes by lumber grade served as dependent variables. Species included are yellow and paper birch, red and sugar maple, yellow-poplar, black cherry, basswood, and northern red, black, white, and chestnut oak.

THE SHORTAGE of high-quality hardwood timber, coupled with an overall price increase, has expanded the usefulness of tree grades for predicting tree quality. The Forest Service has approved and adopted hardwood tree grades for factory lumber (*Hanks 1971*). The lumber grade yields for the three species shown in the 1971 report have been refined, and we are now presenting them here, along with yields for eight additional species. As a result, this report supersedes the 1971 report and includes yields for yellow and paper birch, red and sugar maple, black cherry, yellow-poplar, basswood, and northern red, black, white, and chestnut oak.

This grading system is applicable to standing hardwood trees that contain a grade-3 or better butt log. The lumber grade yields will provide buyers and sellers of timber with the tools necessary for estimating the value of graded trees. The grading system may also serve as the basis for stratifying tree quality during a forest inventory.

BACKGROUND

As I stated in my 1971 paper, there have been several attempts to develop tree grades for hardwoods (*Campbell 1951, 1959; Herrick and Jackson 1957; Hyvarinen 1968; Lucas 1969; Marden 1965; Schroeder 1964*). Most of these have involved single species. The most widely used method was developed by the USDA Forest Service at Carbondale, Ill. (*Herrick and Jackson 1957*). In this system, a tree's grade is equal to the grade of the best 10-foot section of the 16-foot butt log. Another system, used in the Northeast, involves grading each log in the standing tree.

For both of these tree-grading methods, lumber-grade yields for sample trees were estimated from yields of logs sawed in earlier log-grade studies (*Vaughan and others 1966*). In other words, the same lumber-grade volumes were applied to all sections of sample trees that exhibited comparable diameter and log grade. The estimated lumber-grade yields were accepted as actual, and it was understood that variance estimates were not meaningful.

PROCEDURE AND RESULTS

The development of the hardwood tree-grading system is well documented (*Hanks 1971*). For each species we devised a sampling scheme that would result in an even distribution of dbh (diameter at breast height), merchantable height, and quality classes. Number of trees per species ranged from about 150 to 300. They were selected at various geographic locations and processed in groups of 50.

Field procedure for this study involved measuring dbh and merchantable height, estimating scalable defect in the grading section, and determining the grade of each tree. All portions of the stems that qualified as local-use or better (*Rast and others 1973*), were bucked into sawlogs, identified with a tree and log number, and processed into factory lumber. A local-use-class log must scale at least 8 inches inside bark by 8 feet long, and must be one-third sound. The lumber was numbered so that the log and tree from which it came could be identified. Each board was measured and graded by a National Hardwood Lumber Association certified inspector, and all pertinent information was recorded and punched onto data-processing cards.

Predicted dry lumber-grade yields, expressed in board feet, were developed for each species, using multiple-regression techniques. An equation was derived for each lumber grade within the three tree grades (tables 3 to 13). Dbh^2, merchantable height, and dbh^2 x merchantable height were used as independent variables. In some situations where the complete model did not perform as expected, one or more of the independent variables were deleted from the final equation. In four instances where satisfactory equations could not be found, we hand-fit curves through the actual lumber-grade volumes. Curved volumes for the various height and dbh classes were used as observations, and a final equation was derived.

All equations were solved for the desired combinations of dbh and merchantable height, and the resulting lumber-grade volumes were accumulated into lumber-yield tables (tables 14 to 24). A few negative lumber-grade volumes existed for small trees, and these volumes were adjusted to 0.0 board feet.

Tables 25 to 35 contain the lumber-thickness distributions for each species. In most situations, the thickness pattern represents that of sawing for best grade; that is, sawing the thickest potential board, up to 8/4 inches, without lowering the board grade. A different pattern followed in sawing for grade would cause small differences in yield.

Mean lumber-grade yields, standard errors of the residuals, and correlation coefficients are included in tables 36 to 46, and table 47 contains the means and standard deviations for dbh and merchantable height.

APPLICATION

Table 1 contains the specifications of the hardwood tree grades for factory lumber. A tree's grade may be determined by following a stepwise procedure. We suggest the following:

- Measure dbh to the nearest inch.
- Establish the location of all defect indicators—"stoppers",—on the surface of the butt 16-foot log, and then locate the best 12-foot section.

Table 1.—Hardwood tree grades for factory lumber

Grade factor	Tree grade 1			Tree grade 2		Tree grade 3
Length of grading zone (feet)	Butt 16			Butt 16		Butt 16
Length of grading section[a] (feet)	Best 12			Best 12		Best 12
Dbh, minimum (inches)	16[b]			13		10
Diameter, minimum inside bark at top of grading section (inches)	13[b]	16	20	11[c]	12	8
Clear cuttings (on the 3 best faces):[d]						
Length, minimum (feet)	7	5	3	3	3	2
Number on face (maximum)	2			2	3	([e])
Yield in face length (minimum)	5/6			4/6		3/6
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)	9			9[f]		50

[a] Whenever a 14- or 16-foot section of the butt 16-foot log is better than the best 12-foot section, the grade of the longer section will become the grade of the tree. This longer section, when used, is the basis for determining the grading factors such as diameter and cull deduction.

[b] In basswood and ash, dib at top of grading section must be 12 inches and dbh must be 15 inches.

[c] Grade 2 trees can be 10 inches ib at top of grading section if otherwise meeting surface requirements for small grade 1s.

[d] A clear cutting is a portion of a face free of defects, extending the width of the face. A face is one-fourth of the surface of the grading section as divided lengthwise.

[e] Unlimited.

[f] Fifteen percent crook and sweep or 40 percent total cull deduction are permitted in grade 2 if size and surface of grading section qualify as grade 1. If rot shortens the required clear cuttings to the extent of dropping the butt log to grade 2, do not drop the tree's grade to 3 unless the cull deduction for rot is greater than 40 percent.

- Estimate inside bark diameter at top of the 12-foot section to the nearest inch.
- Estimate scalable defect in the 12-foot section selected previously.
- The grade of the 12-foot section becomes the tree's grade, unless the grade can be improved by using a 14- or 16-foot section.

Those already familiar with the U. S. Forest Service log grades will note that the scalable defect limitations for the tree grades differ from the log-grade limitations; that is, grade-1 logs may contain up to 40 percent defect while the grading section of grade-1 trees is limited to 9 percent defect. The reason for this difference is that, when grading trees, a large rot may be eliminated from the grading section by grading the best 12-foot section. In these situations, rot in the entire 16-foot butt log may approach 40 percent.

It should be noted that both dbh and inside-bark diameter at the top of the grading section must satisfy the minimum requirements of the assigned tree grade. By measuring these items on a number of felled trees, a relationship can be developed between dbh and inside bark diameters at 12, 14, and 16 feet above stump height. An example of this may be found in table 2. This table, however, is based on a form class of 82 and should be used only if the trees being graded meet this level of tree form.

Several factors determine the location of the best 12-foot grading section within the 16-foot grading zone. Some examples are:

1. If the deduction for rot in the butt 12 feet exceeds 9 percent, estimate rot in the top 12-foot section. The grade may go up if the estimate is 9 percent or less (fig. 1).
2. If defect indicators are clustered in the top part of the grading zone, the butt 12 feet may be the best grading section (fig. 2).
3. If the inside-bark diameter at the top of the grading zone is too small for the grade, drop back 4 feet to see if diameter has increased to the minimum for the grade (fig. 3).
4. If a crook is located near an end of the grading zone, the location of the best 12-foot section may be influenced (fig. 4).

During field demonstrations of the tree grades, questions have often arisen about how much cull is allowed in grade 2 trees. If a tree is big enough and the surface is clear enough for grade 1, but its grading section has 10 to 15 percent sweep or 10 to 40 percent total cull, it is a grade-2 tree. Examples would be a tree with a cat face (fig. 5) or a large internal rot (fig. 6).

Most surface rots, unless very shallow, and some internal rots, are considered "stoppers" in grading the surface. In those cases where the rot drops the surface of the grading section from grade 1 to grade 2, do not drop the tree to grade 3 unless the rot deduction exceeds 40 percent. Leave the tree in grade 2.

Use of the lumber-grade volume tables or equations requires the following field data for each tree:

Text continues on page 5.

Table 2. Minimum dbh required to meet dib limitations[a]

Tree grade	Position of grading section, feet			Minimum length of clear cutting
	0 - 12	2 - 14	4 - 16	
	Inches	*Inches*	*Inches*	*Feet*
1	13.2[b]	13.7[b]	14.1[b]	10
	14.5	15.0	15.4	10
	17.9	18.6	19.0	5
	22.5	23.3	23.9	3
2	11.0	11.4	11.7	(c)
	12.2	12.6	12.9	3
3	8.9	9.1	9.3	2

[a] Based on a form class of 82.

[b] For basswood and ash only.

[c] grade-1 surface.

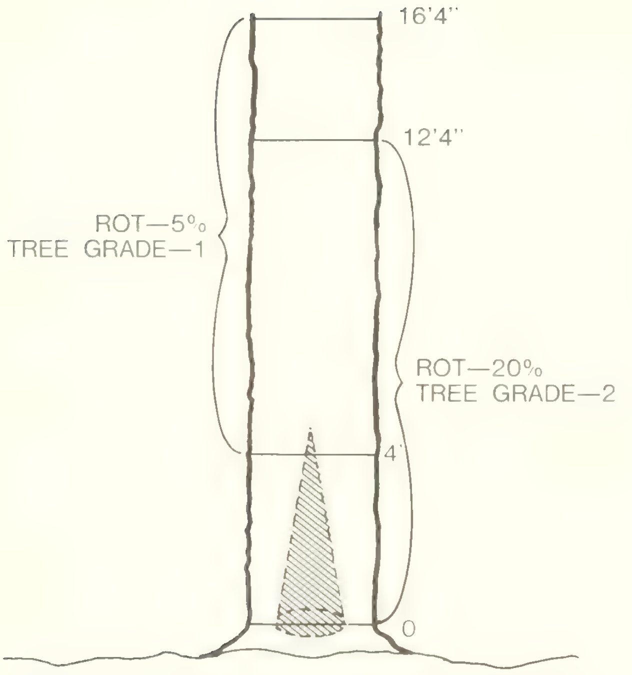

Figure 1.—Large rot at base of tree. Because of rot, the grade of the butt 12-foot section is 2. By grading the top 12-foot section, the tree's grade can be raised to 1.

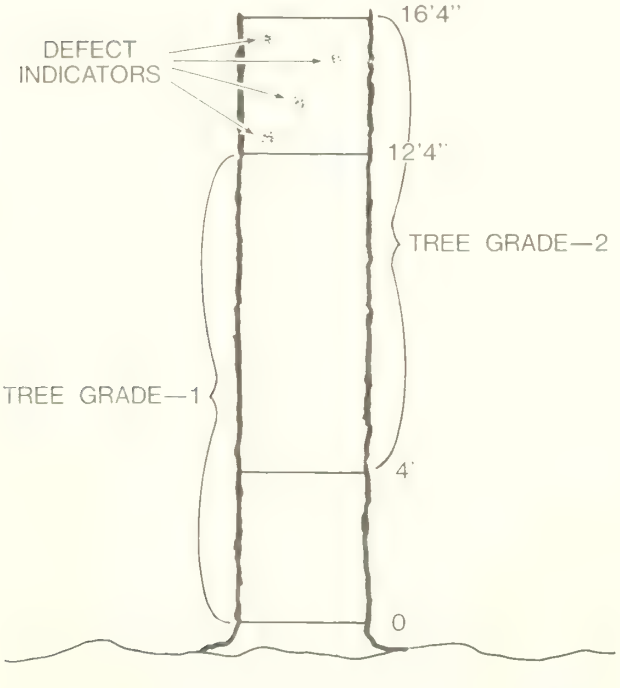

Figure 2.—Defect indicators clustered at top of grading zone. The best 12-foot section is the butt 12 feet.

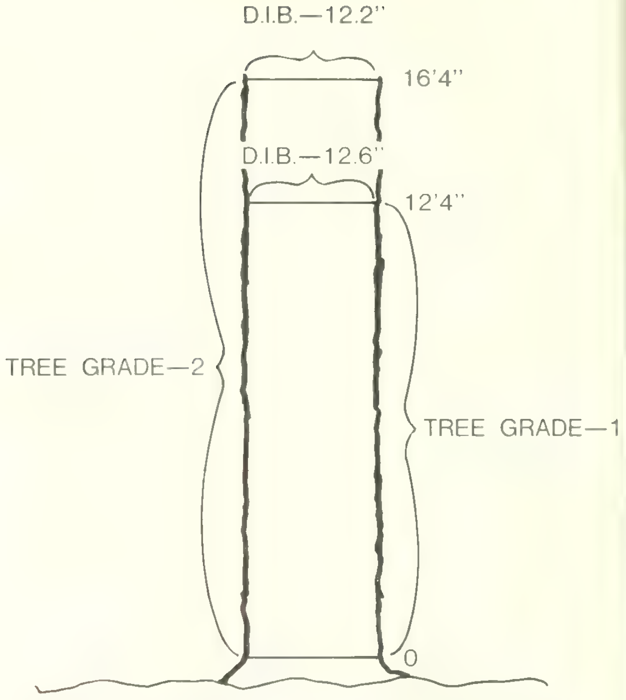

Figure 3.—Relationship between dib (diameter inside bark) and tree grade. The dib at 16 feet 4 inches above the stump is not large enough for grade 1. However, at 12 feet 4 inches the dib meets grade-1 requirements.

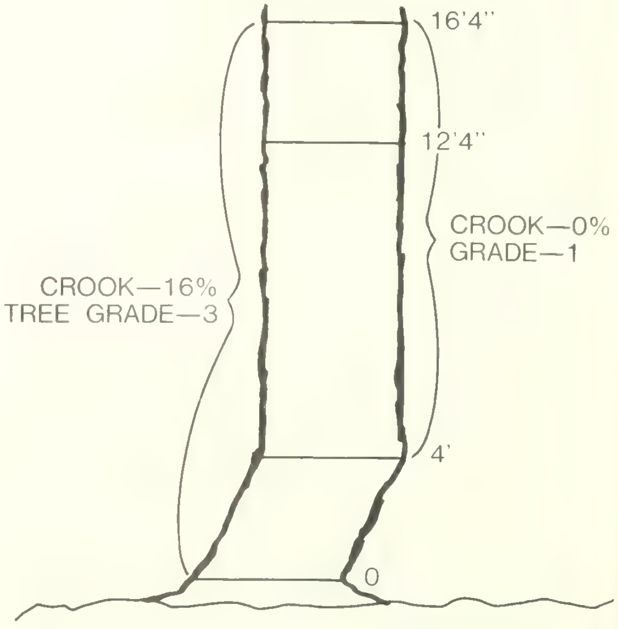

Figure 4.—Crook at base of tree. Because of crook, the butt 12-foot section is grade 3. Therefore, grade the top 12-foot section and raise the grade to 1.

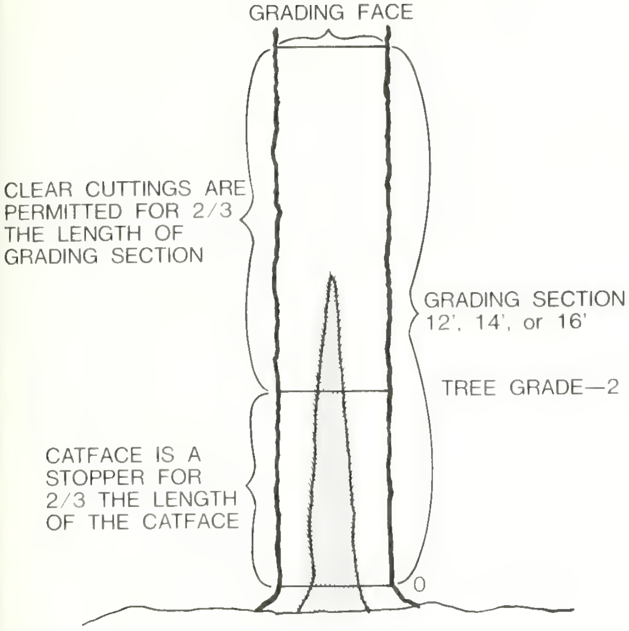
GRADING FACE
CLEAR CUTTINGS ARE PERMITTED FOR 2/3 THE LENGTH OF GRADING SECTION
GRADING SECTION 12', 14', or 16'
TREE GRADE—2
CATFACE IS A STOPPER FOR 2/3 THE LENGTH OF THE CATFACE
0

Figure 5.—Effect of catface on tree grade. Because of catface, the surface is grade 2 and not grade 1. Total cull is between 10 and 40 percent. Do not drop the tree's grade to 3; leave it at 2.

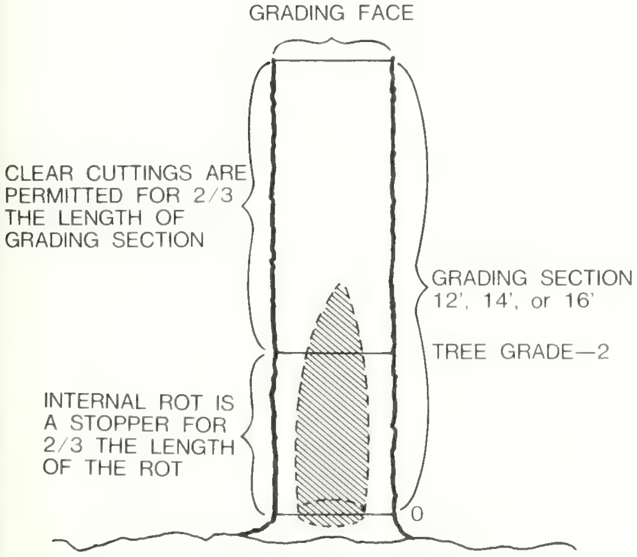
GRADING FACE
CLEAR CUTTINGS ARE PERMITTED FOR 2/3 THE LENGTH OF GRADING SECTION
GRADING SECTION 12', 14', or 16'
TREE GRADE—2
INTERNAL ROT IS A STOPPER FOR 2/3 THE LENGTH OF THE ROT
0

Figure 6.—Effect of internal rot on tree grade. Because of internal rot, the surface is grade 2 and not grade 1. Total cull is between 10 and 40 percent. Do not drop the tree's grade to 3; leave it at 2.

- Species
- Tree grade
- Dbh to the nearest inch
- Merchantable height to the nearest foot as measured from the top of a 1-foot stump to the point where local-use material ends. For forked trees, consider only the longest fork.

If the user is certain that prediction will be based on the tabular volumes, merchantable height should be estimated to the nearest half-log. However, if the equations are used to estimate lumber-grade volumes, accuracy can be improved if height to the nearest foot is recorded.

The predicted dry-lumber-grade volumes are net volumes derived from actual mill yields and should not be adjusted for cull or overrun.

When estimating the value of lumber contained in a tree, apply current dry-lumber prices to the estimated lumber-grade volumes and sum the values as shown below:

Species : Black Oak
Tree grade : 1
Dbh : 20 inches
Merchantable height : 32 feet

Lumber grade	*Predicted Volume* (bd. ft.)*	*Lumber price per M bd. ft.*	*Lumber value*
FAS	19.6	$370	$ 7.25
FAS1F	31.7	360	11.41
Selects	6.2	350	2.17
No. 1C	78.5	240	18.84
No. 2C	57.2	120	6.86
SW	12.2	115	1.40
No. 3A	55.8	110	6.14
No. 3B	20.5	95	1.95
Totals	281.7	— —	$56.02

*See table 16.

If desirable, a lumber-grade price may be weighted in proportion to the volume that a sawmill is producing in each lumber grade and thickness class, as in the following example (Firsts and Seconds):

Thickness class (inches)	*Percent of volume*	*Price*
4/4	50	$370/M bd. ft.
5/4	25	372/M bd. ft.
6/4	25	395/M bd. ft.
	FAS weighted price	376.75/M bd. ft.

Interpretation and application of the tree-grade specifications will prove relatively easy for those already familiar with the hardwood log grades. However, for those who have not encountered hardwood log grading, we suggest the following publications as useful references:

1. A GUIDE TO HARDWOOD LOG GRADING (rev.). Rast, Everette D., David L. Sonderman, and Glenn L. Gammon. 1973. USDA For. Serv. Tech. Rep. NE-1. 32 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.
2. HARDWOOD LOG GRADES FOR STANDARD LUMBER. Vaughan, C. L., A. C. Wollin, K. A. McDonald, and E. H. Bulgrin. 1966. USDA For. Serv. Res. Pap. FPL-63. 52p., illus. For. Prod. Lab., Madison, Wis.
3. GRADE DEFECTS IN HARDWOOD TIMBER. Lockard, C. R., J. A. Putnam, and R. D. Carpenter. 1963. USDA Agric. Handb. 244 39p., illus.
4. DEFECT INDICATORS IN SUGAR MAPLE. Marden, Richard M., and Charles L. Stayton. 1970. USDA For. Serv. Res. Pap. NC-37, 29p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Those seeking a discussion of how to estimate deductions for sweep and crook are referred to reference 1 above (p. 25). Because the defect is visible, the deduction for sweep or crook in the standing tree should be comparable to that for a log on the ground.

The chore of estimating interior defect is more difficult and subjective. Some insight into the art of scaling interior cull in trees may be gained from reference 1 above and from the following:

1. ESTIMATING DEFECT IN TREE-LENGTH HARDWOODS. Nyland, Ralph D. 1970. North. Logger 18(8): 30, 54.
2. A PHOTO GUIDE TO THE PATTERNS OF DISCOLORATION AND DECAY IN LIVING NORTHERN HARDWOOD TREES. Shigo, Alex L., and Edwin vH. Larson. 1969. USDA For. Serv. Res. Pap. NE-127, 100 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.
3. SHORTCUTS FOR CRUISERS AND SCALERS. L. R. Grosenbaugh. 1952. USDA For. Serv. South. For. Exp. Stn. Occas. Pap. 126: 14-15, South. For. Exp. Stn., New Orleans, La.

DISCUSSION

Although the hardwood tree grades presented here represent a relatively recent development, the specifications for grading the surface of the butt logs are the same that appear in the Standard Forest Service Log Grades — grades that have been used for 35 years. Furthermore, the practice of grading a tree's butt section has been used successfully by the Forest Service. Therefore we expect users to readily adapt to the application of the tree grades.

We conducted a series of 11 field trials on 7 species. This was done to demonstrate how well lumber volume and value could be predicted in tree populations outside the original sample used in yield development. Results from the field trials indicate that for groups of approximately 50 trees, actual and predicted total lumber volume may differ by 10 percent, although 5 percent was average. Actual and predicted total lumber value may differ by 14 percent, but 6 percent was average. In a few trials, volume and value differences were greater than these. However, atypical conditions existed both in the timber and in the method of sawing.

We have asked the question: Do the tree grades separate groups of trees into grades with meaningful value differences? Previous research on log- and tree-grading systems established the standard that value differences between grades should be at least 10 percent. For the 11 hardwood species, differences between tree grades 1 and 2 ranged from 5 percent to 20 percent at mean dbh and height while differences between tree grades 2 and 3 ranged from 10 percent to 27 percent. Greater value separation between grades 1 and 2 might be possible for selected species, but modifications in the tree-grade specifications would be necessary. The confusion caused by such modifications would more than offset the possible gains.

Hardwood tree grades and lumber-grade yields for 11 species are available for use when factory lumber is the end product of sawing. If a sawmill deviates from producing factory lumber, the predicted lumber volumes will not apply. Value prediction may be reasonable, but some checking is recommended to substantiate the ability to predict value.

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Table 3.—Regression equations for YELLOW BIRCH

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	−81.6	0.25084	0.9478	—
FAS1F	4.9	.06269	—	—
Selects	.9	.00458	.1614	—
No. 1C	42.7	−.07439	−2.2197	0.009403
No. 2C	75.0	−.13688	−1.5430	.006463
No. 3A	29.6	−.07673	−.4814	.003595
No. 3B	−16.1	.06006	.8727	−.000553
		TREE GRADE 2		
FAS	−31.3	0.10494	0.5159	−0.000243
FAS1F	−.15.9	.06511	.4257	−.000395
Selects	3.7	.00242	.0495	—
No. 1C	−52.7	.25423	1.7080	−.003374
No. 2C	−5.2	.01883	.4377	.002703
No. 3A	−16.0	.06754	1.1508	−.000963
No. 3B	−4.8	.02837	.1856	.001751
		TREE GRADE 3		
FAS	0.9	−0.00197	0.0494	0.000301
FAS1F	−.4	.00701	−.0677	.000735
Selects	1.3	.00229	—	—
No. 1C	−35.8	.19206	.6504	—
No. 2C	.9	−.06329	.4244	.005634
No. 3A	−32.7	.15298	1.5680	−.002739
No. 3B	.2	08238	.5935	−.001215

Table 4.—Regression equations for RED MAPLE

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	107.0	−0.32016	−3.2156	0.013067
FAS1F	−55.7	.17503	1.2690	−.001008
Selects	33.9	−.09531	−.6961	.002937
No. 1C	−58.6	.26467	.5604	−.000106
No. 2A	−59.0	.21877	1.7695	−.002140
No. 2B	23.1	—	.6110	—
No. 3A	−3.1	—	.5536	—
No. 3B	−18.8	.02797	.4187	.000139
		TREE GRADE 2		
FAS	50.1	−0.19679	−1.9356	0.009389
FAS1F	36.0	−.11245	−1.1578	.006010
Selects	7.9	−.02157	−.0667	.001043
No. 1C	−35.9	.21697	.4824	−.000330
No. 2A	−62.8	.25951	2.5908	−.004669
No. 2B	20.6	.00823	.6919	—
No. 3A	−5.6	.03546	.3150	—
No. 3B	−31.3	.12511	.4546	−.001094
		TREE GRADE 3		
FAS	−3.6	0.03176	0.0160	—
FAS1F	3.3	−.03651	−.2691	0.002968
Selects	−9.2	.03157	.3783	−.000581
No. 1C	−21.0	.18789	.1210	—
No. 2A	−17.1	.06125	.6576	.002633
No. 2B	−10.6	.02622	1.6818	—
No. 3A	−2.3	.04847	.1145	.000231
No. 3B	−2.9	.04757	—	—

Table 5.—Regression equations for BLACK OAK

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	−60.0	0.13438	—	0.002016
FAS1F	26.5	—	−1.1406	.003254
Selects	−5.7	.02958	—	—
No. 1C	−28.4	.11351	−.3191	.005598
No. 2C	−56.1	.10709	2.2017	—
SW	−5.3	—	.5450	—
No. 3A	−2.1	.02392	1.5106	—
No. 3B	−61.6	.02265	2.2822	—
		TREE GRADE 2		
FAS	-17.7	0.09984	—	—
FAS1F	−2.5	.06558	-0.4383	0.001269
Selects	−15.1	.03128	.4242	−.000571
No. 1C	−84.4	.30007	.2915	.003256
No. 2C	−3.3	.01344	−.0405	.005019
SW	-13.6	—	.6290	—
No. 3A	2.7	−.00256	.8560	.001574
No. 3B	11.2	−.04786	.9299	.000673
		TREE GRADE 3		
FAS	2.8	−0.01046	−0.3083	0.001659
FAS1F	-11.1	.07472	—	—
Selects	4.0	−.01437	−.1836	.000819
No. 1C	−35.9	.28699	—	—
No. 2C	−33.7	.15043	1.2812	−.000197
SW	−10.6	.04646	.7109	−.001239
No. 3A	−35.0	.21014	1.8795	−.004353
No. 3B	8.6	−.22690	1.1022	.006792

Table 6.—Regression equations for BASSWOOD

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	109.2	−0.28506	−3.8748	0.013515
Selects	46.2	−.05390	−.6958	.003807
No. 1C	−42.6	.15964	1.4745	−.000487
No. 2C	−48.4	.27756	1.7276	−.001370
No. 3C	−94.0	.32304	1.6243	−.003752
		TREE GRADE 2		
FAS	34.4	−0.14665	−1.2592	0.006328
Selects	2.7	.02116	−.5684	.004110
No. 1C	−73.1	.19879	2.3763	−.001908
No. 2C	−31.4	.14176	2.4489	−.001547
No. 3C	37.8	−.06258	−1.7140	.006367
		TREE GRADE 3		
FAS	−5.1	0.00443	0.1479	0.000396
Selects	10.4	−.07589	−.3836	.003898
No. 1C	−27.7	.11870	.8929	—
No. 2C	−29.8	.23438	1.2059	.001412
No. 3C	14.8	−.01777	−.4513	.003582

Table 7.—Regression equations for SUGAR MAPLE

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	−13.7	0.04397	−0.5012	0.003110
FAS1F	−5.1	.09560	.2343	—
Selects	8.7	—	—	—
No. 1C	64.4	−.08478	−2.5900	.009585
No. 2C	−20.2	.17790	.6335	−.000416
No. 3A	17.9	−.02044	−.0217	.001842
No. 3B	−49.2	.15884	1.7636	−.002061
		TREE GRADE 2		
FAS	−1.1	0.02014	−0.1342	0.001130
FAS1F	−26.2	.10385	.5039	—
Selects	7.6	—	—	—
No. 1C	−47.9	.23097	.2012	.002139
No. 2C	−34.0	.14299	1.1578	.000284
No. 3A	−9.6	.01312	.8717	.000694
No. 3B	33.7	.09204	−.3045	.003507
		TREE GRADE 3		
FAS	3.6	−0.01538	−0.2051	0.001103
FAS1F	−9.9	.06014	.1904	−.000541
Selects	—	.01602	—	—
No. 1C	−32.4	.19398	.4660	—
No. 2C	17.1	−.03144	−.8246	.006521
No. 3A	−40.0	.15978	1.7973	−.002380
No. 3B	.4	−.01007	1.1382	.001620

Table 8.—Regression equations for BLACK CHERRY

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
TREE GRADE 1				
FAS	110.9	−0.18419	−3.4974	0.011488
Selects	−43.8	.21162	.7202	−.000161
No. 1C	−95.9	.38336	1.4001	−.001491
No. 2C	−27.5	.05552	.9407	.002457
No. 3A	−25.4	.02206	1.1106	.000837
No. 3B	67.5	−.18435	−1.5782	.005124
TREE GRADE 2				
FAS	−3.5	−0.05135	0.0617	0.003854
Selects	−25.6	.17841	.7826	−.001686
No. 1C	37.8	−.00649	−2.2041	.009231
No. 2C	10.4	.01246	.0272	.003999
No. 3A	−11.3	—	1.2522	—
No. 3B	−13.5	.03282	.4948	−.000545
TREE GRADE 3				
FAS	16.5	−0.05599	−0.8881	0.004326
Selects	26.9	−.09182	−1.2561	.006970
No. 1C	−5.3	.15258	−.7888	.004838
No. 2C	7.5	.00264	.0970	.004426
No. 3A	−11.3	−.00565	1.1213	.001695
No. 3B	−2.7	—	.3912	—

Table 9.—Regression equations for PAPER BIRCH

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	2.2	0.07949	—	—
Selects	22.5	.00517	−0.6339	0.003136
No. 1C	64.0	−.09816	−2.5230	.008699
No. 2C	18.5	.03261	−.3408	.002549
No. 3A	11.2	−.06827	.0370	.003951
No. 3B	−21.7	.04683	.4569	.001223
		TREE GRADE 2		
FAS	21.5	−0.07949	−0.8054	0.004026
Selects	−4.9	.10336	—	—
No. 1C	2.7	.04559	−.3964	.003121
No. 2C	−19.8	.09414	1.0262	−.000384
No. 3A	7.9	−.03529	.4357	.002375
No. 3B	−49.6	.18132	1.7580	−.004147
		TREE GRADE 3		
FAS	1.8	−0.00536	−0.1860	0.001199
Selects	−1.8	−.00035	.1821	.000729
No. 1C	−5.6	.07005	−.1877	.002719
No. 2C	26.0	−.09513	−1.0028	.008604
No. 3A	−4.6	.06537	.4518	.000977
No. 3B	−9.8	.04146	.8444	−.000241

Table 10.—Regression equations for WHITE OAK

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
TREE GRADE 1				
FAS	−28.1	0.14529	—	—
FAS1F	−18.7	.11180	—	—
Selects	−22.2	.04969	0.4580	0.000480
No. 1C	108.4	−.19983	−4.4359	.013753
No. 2C	−56.0	.09960	1.2974	.002826
SW	28.7	−.11561	−.8389	.004292
No. 3A	−45.7	.11320	1.8333	−.001263
No. 3B	12.1	−.00190	.2693	.000729
TREE GRADE 2				
FAS	−5.9	0.04411	—	—
FAS1F	−5.4	.05429	—	—
Selects	3.9	—	—	—
No. 1C	−76.6	.31380	0.3714	0.001272
No. 2C	−16.5	.04747	−.3176	.006428
SW	−40.1	.06239	1.2224	.000041
No. 3A	10.9	−.01994	.0326	.003148
No. 3B	5.5	—	.8050	—
TREE GRADE 3				
FAS	−3.2	0.02246	—	—
FAS1F	−2.9	.02426	—	—
Selects	−.7	—	0.0626	—
No. 1C	40.3	−.00140	−2.4347	0.007322
No. 2C	3.8	.03150	−.7755	.007095
SW	−10.0	.01386	.1206	.002470
No. 3A	−20.2	.08689	.8922	.000424
No. 3B	−17.9	.03783	1.7125	−.000545

Table 11.—Regression equations for YELLOW-POPLAR

Dependent variable lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	−8.2	0.02163	−0.0131	0.000215
Selects	−16.7	.03821	.1187	.000371
Saps	−5.5	.05463	—	—
No. 1C	−120.9	.64541	.4077	−.000501
No. 2A	37.1	.31819	1.6896	−.000683
No. 2B	71.2	−.40556	−.7508	.010092
No. 3C	−15.6	.04544	.3578	−.000804
		TREE GRADE 2		
FAS	−1.2	0.00611	—	—
Selects	2.3	.00148	−0.1785	0.000673
Saps	−7.7	.04519	.1969	−.000422
No. 1C	105.0	.52277	.6201	.000233
No. 2A	121.6	−.25395	−2.6390	.013732
No. 2B	34.6	−.02823	1.4237	.002825
No. 3C	4.3	.02673	—	—
		TREE GRADE 3		
FAS	0.0	—	—	—
Selects	5.3	−0.03049	−0.1169	0.000794
Saps	.5	.00932	—	—
No. 1C	53.5	.38486	—	—
No. 2A	61.8	.10816	−2.0912	0.011603
No. 2B	113.8	.38428	2.9479	0.002172
No. 3C	5.3	.00916	—	—

Table 12.—Regression equations for NORTHERN RED OAK

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS	−10.6	0.13317	−1.5709	0.005175
FAS1F	−22.6	.02716	.0842	.002815
Selects	13.7	−.01711	−.3370	.001016
No. 1C	57.2	−.00508	−2.7014	.009354
No. 2C	−78.4	.10362	3.7351	−.000884
No. 3A	50.3	−.04598	−.5081	.001796
No. 3B	−8.9	.02341	.1077	.000397
		TREE GRADE 2		
FAS	53.2	0.12214	0.9548	—
FAS1F[a]	38.0	−.06613	−1.0022	0.003832
Selects	3.7	—	—	—
No. 1C[a]	−6.1	.01520	−.8778	.008854
No. 2C	−57.2	.09975	2.4582	.000878
No. 3A	−55.0	.11825	2.3546	−.002127
No. 3B	3.5	−.00245	−.0156	.000731
		TREE GRADE 3		
FAS	5.9	−0.02210	−0.3208	0.001560
FAS1F	−5.2	.02821	.0096	.000504
Selects	2.0	—	—	—
No. 1C	−22.6	.20603	−0.0718	.000451
No. 2C	−21.1	.21713	.2132	.000399
No. 3A	12.0	.06393	1.1422	.000741
No. 3B	−8.3	.00011	.8556	.002338

[a] Coefficients for this lumber grade were derived from a least-squares fit through hand-adjusted curves.

Table 13.—Regression equations for CHESTNUT OAK

Dependent variable: lumber grade	Independent variables			
	Constant	Dbh^2	Merchantable height	Dbh^2 x Merchantable height
		TREE GRADE 1		
FAS[a]	22.0	−0.04870	−0.9054	0.003100
FAS-WHND	−59.1	.13433	.9518	−.000049
FAS1F	−18.6	.05098	.3654	—
FAS1F-WHND	−7.1	.03857	—	—
Selects	3.2	—	—	—
Selects-WHND	1.3	—	—	—
No. 1C[a]	2.9	.04422	−.3517	.002009
No. 1C-WHND	−29.7	.10000	−.2710	.002918
No. 2C	42.6	−.06705	−.3753	.002018
SW	−24.6	.00708	1.3434	.000921
No. 3A	−12.2	.07961	.4935	—
No. 3B	−40.0	.21600	—	—
		TREE GRADE 2		
FAS	−2.6	−0.00307	0.1836	0.000062
FAS-WHND	−28.5	.13196	—	—
FAS1F	−8.0	.04270	—	—
FAS1F-WHND	11.9	−.01829	−.5179	.001491
Selects	23.3	−.05727	−.5522	.001551
Selects-WHND	−3.3	.00708	.0624	−.000039
No. 1C	29.0	−.05431	−.4617	.002022
No. 1C-WHND	−6.8	.06449	−.7515	.003901
No. 2C	−10.4	.03866	.7905	−.000655
SW	−31.5	.02667	1.6136	—
No. 3A	30.0	−.04253	−.0981	.002108
No. 3B	−35.1	.17156	.6519	—
		TREE GRADE 3		
FAS	0.0	—	—	—
FAS-WHND	−6.5	0.04418	—	—
FAS1F	.4	−.00078	−0.0560	0.000300
FAS1F-WHND	−4.5	.01459	.0661	—
Selects	1.1	—	—	—
Selects-WHND	.4	—	—	—
No. 1C	12.8	−.08596	−.3755	.003710
No. 1C-WHND	13.6	.00870	−1.1844	.004885
No. 2C	−6.7	.03098	.3781	—
SW	−1.8	−.04001	.3506	.003510
No. 3A	−20.3	.07085	1.1497	−.000482
No. 3B	14.3	−.02160	−.9057	.007928

[a] Coefficients for this lumber grade were derived from a least-squares fit through hand-adjusted curves.

Table 14.—Lumber grade volume for YELLOW BIRCH

[In board feet]

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 1 1-1/2 LOGS							
16	5.4	20.9	5.9	28.2	42.6	20.5	16.8
17	13.6	23.0	6.1	33.1	43.2	20.8	18.4
18	22.4	25.2	6.3	38.4	43.9	21.1	20.0
19	31.7	27.5	6.4	44.0	44.5	21.5	21.7
20	41.5	30.0	6.6	49.9	45.3	21.9	23.6
21	51.8	32.5	6.8	56.1	46.0	22.3	25.5
22	62.6	35.2	7.0	62.6	46.8	22.7	27.5
23	73.8	38.1	7.2	69.5	47.6	23.1	29.6
24	85.6	41.0	7.4	76.6	48.5	23.5	31.8
25	97.9	44.1	7.6	84.0	49.4	24.0	34.1
26	110.7	47.3	7.9	91.7	50.3	24.5	36.5
TREE GRADE 1 2 LOGS							
16	12.9	20.9	7.2	29.7	43.5	24.0	22.7
17	21.2	23.0	7.4	37.1	45.8	25.3	24.1
18	30.0	25.2	7.5	45.1	48.3	26.6	25.6
19	39.3	27.5	7.7	53.4	50.9	28.0	27.1
20	49.1	30.0	7.9	62.3	53.6	29.5	28.8
21	59.4	32.5	8.1	71.6	56.5	31.1	30.5
22	70.1	35.2	8.3	81.3	59.5	32.7	32.3
23	81.4	38.1	8.5	91.5	62.6	34.5	34.2
24	93.2	41.0	8.7	102.1	65.9	36.3	36.2
25	105.5	44.1	8.9	113.2	69.3	38.1	38.3
26	118.3	47.3	9.2	124.8	72.9	40.1	40.5
27	131.6	50.6	9.4	136.8	76.6	42.1	42.7
28	145.4	54.0	9.7	149.3	80.5	44.2	45.0
29	159.7	57.6	9.9	162.2	84.4	46.4	47.5
30	174.5	61.3	10.2	175.5	88.6	48.7	50.0
TREE GRADE 1 2-1/2 LOGS							
16	20.5	20.9	8.5	31.2	44.4	27.5	28.5
17	28.8	23.0	8.7	41.1	48.4	29.7	29.8
18	37.6	25.2	8.8	51.7	52.7	32.1	31.1
19	46.9	27.5	9.0	62.8	57.2	34.6	32.5
20	56.6	30.0	9.2	74.6	61.9	37.2	34.0
21	66.9	32.5	9.4	87.0	66.9	39.9	35.5
22	77.7	35.2	9.6	99.9	72.2	42.8	37.2
23	89.0	38.1	9.8	113.5	77.6	45.8	38.9
24	100.8	41.0	10.0	127.7	83.3	49.0	40.7
25	113.1	44.1	10.2	142.5	89.3	52.3	42.5
26	125.9	47.3	10.5	157.9	95.5	55.7	44.5
27	139.2	50.6	10.7	173.9	102.0	59.2	46.5
28	153.0	54.0	10.9	190.5	108.6	62.9	48.6
29	167.3	57.6	11.2	207.7	115.6	66.7	50.7
30	182.1	61.3	11.5	225.5	122.8	70.7	53.0
TREE GRADE 1 3 LOGS							
16	28.1	20.9	9.8	32.7	45.3	31.0	34.4
17	36.4	23.0	10.0	45.1	51.0	34.2	35.5
18	45.2	25.2	10.1	58.3	57.1	37.5	36.6
19	54.4	27.5	10.3	72.2	63.5	41.1	37.9
20	64.2	30.0	10.5	86.9	70.3	44.8	39.2
21	74.5	32.5	10.7	102.4	77.4	48.8	40.6
22	85.3	35.2	10.9	118.6	84.8	52.9	42.0
23	96.6	38.1	11.1	135.6	92.6	57.2	43.5

CONTINUED

Table 14.—Continued: YELLOW BIRCH

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
24	108.4	41.0	11.3	153.3	100.8	61.7	45.1
25	120.7	44.1	11.5	171.8	109.3	66.4	46.7
26	133.5	47.3	11.7	191.0	118.1	71.3	48.4
27	146.8	50.6	12.0	211.0	127.3	76.4	50.2
28	160.6	54.0	12.2	231.7	136.8	81.6	52.1
29	174.9	57.6	12.5	253.2	146.7	87.1	54.0
30	189.7	61.3	12.8	275.4	156.9	92.7	56.0
TREE GRADE 2 1 LOG							
13	0.0	0.8	4.9	8.5	12.3	11.2	7.7
14	.0	2.4	5.0	13.9	14.0	12.6	9.2
15	.0	4.1	5.0	19.7	15.8	14.1	10.9
16	2.8	6.0	5.1	25.9	17.7	15.8	12.6
17	6.2	7.9	5.2	32.5	19.7	17.5	14.5
18	9.7	10.0	5.3	39.5	21.9	19.3	16.4
19	13.4	12.1	5.4	46.9	24.2	21.2	18.5
20	17.4	14.4	5.5	54.7	26.6	23.3	20.7
21	21.5	16.8	5.6	62.9	29.2	25.4	23.0
22	25.9	19.4	5.7	71.5	31.8	27.6	25.5
23	30.4	22.0	5.8	80.6	34.6	30.0	28.0
24	35.2	24.8	5.9	90.0	37.6	32.4	30.6
TREE GRADE 2 1-1/2 LOGS							
13	0.0	3.7	5.3	17.6	19.5	19.1	11.6
14	.5	5.2	5.4	22.2	21.7	20.3	13.5
15	3.4	6.8	5.4	27.3	24.1	21.6	15.5
16	6.5	8.6	5.5	32.6	26.7	23.0	17.7
17	9.7	10.4	5.6	38.4	29.5	24.5	20.0
18	13.2	12.3	5.7	44.4	32.4	26.0	22.5
19	16.9	14.4	5.8	50.8	35.5	27.7	25.1
20	20.7	16.6	5.9	57.6	38.8	29.4	27.8
21	24.8	18.8	6.0	64.7	42.2	31.2	30.7
22	29.0	21.2	6.1	72.1	45.8	33.1	33.7
23	33.5	23.7	6.2	79.9	49.6	35.1	36.9
24	38.2	26.4	6.3	88.1	53.5	37.2	40.2
TREE GRADE 2 2 LOGS							
13	1.6	6.6	5.7	26.7	26.6	27.0	15.4
14	4.3	8.0	5.8	30.6	29.5	28.0	17.7
15	7.1	9.5	5.8	34.9	32.5	29.1	20.1
16	10.1	11.2	5.9	39.4	35.8	30.2	22.7
17	13.3	12.9	6.0	44.2	39.2	31.4	25.5
18	16.7	14.7	6.1	49.3	42.9	32.7	28.5
19	20.3	16.7	6.2	54.8	46.8	34.1	31.6
20	24.1	18.7	6.3	60.5	50.9	35.5	34.9
21	28.1	20.9	6.4	66.5	55.3	37.0	38.4
22	32.2	23.1	6.5	72.7	59.8	38.6	42.0
23	36.6	25.5	6.6	79.3	64.5	40.3	45.8
24	41.2	27.9	6.7	86.2	69.5	42.0	49.8
TREE GRADE 2 2-1/2 LOGS							
13	5.4	9.5	6.1	35.8	33.8	34.9	19.3
14	8.0	10.8	6.2	39.0	37.2	35.7	21.9
15	10.8	12.2	6.2	42.5	40.9	36.6	24.8
16	13.7	13.8	6.3	46.2	44.8	37.5	27.8
17	16.9	15.4	6.4	50.1	49.0	38.4	31.1

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Table 14.—Continued: YELLOW BIRCH

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
18	20.2	17.1	6.5	54.3	53.4	39.4	34.5
19	23.7	18.9	6.6	58.7	58.1	40.5	38.1
20	27.4	20.9	6.6	63.3	63.1	41.6	42.0
21	31.3	22.9	6.7	68.2	68.3	42.8	46.0
22	35.4	25.0	6.9	73.3	73.8	44.1	50.3
23	39.7	27.2	7.0	78.7	79.5	45.4	54.7
24	44.2	29.5	7.1	84.3	85.4	46.7	59.3

TREE GRADE 2
3 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
13	9.2	12.3	6.5	44.9	40.9	42.8	23.1
14	11.7	13.6	6.6	47.4	44.9	43.4	26.1
15	14.5	14.9	6.6	50.0	49.2	44.0	29.4
16	17.3	16.3	6.7	52.9	53.8	44.7	32.9
17	20.4	17.9	6.8	56.0	58.7	45.4	36.6
18	23.7	19.5	6.9	59.2	63.9	46.1	40.5
19	27.1	21.2	6.9	62.6	69.4	46.9	44.7
20	30.8	23.0	7.0	66.2	75.2	47.8	49.1
21	34.6	24.9	7.1	70.0	81.3	48.6	53.7
22	38.6	26.9	7.2	73.9	87.7	49.6	58.5
23	42.8	28.9	7.4	78.1	94.4	50.5	63.6
24	47.2	31.1	7.5	82.4	101.4	51.5	68.9

TREE GRADE 3
1 LOG

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
10	0.4	0.4	1.5	0.0	10.4	3.3	16.0
11	.5	.8	1.6	.0	10.9	5.6	17.3
12	.5	1.2	1.6	2.3	11.6	8.1	18.8
13	.6	1.7	1.7	7.1	12.2	10.8	20.3
14	.7	2.2	1.7	12.3	13.0	13.8	22.0
15	.7	2.7	1.8	17.8	13.7	16.9	23.9
16	.8	3.3	1.9	23.8	14.6	20.3	25.8
17	.9	3.9	2.0	30.1	15.5	23.9	27.9
18	1.0	4.6	2.0	36.8	16.4	27.8	30.1
19	1.1	5.3	2.1	43.9	17.4	31.8	32.4
20	1.2	6.0	2.2	51.4	18.4	36.1	34.9

TREE GRADE 3
1-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
10	0.2	0.4	1.5	0.0	18.3	13.7	19.8
11	.4	1.0	1.6	3.0	19.8	15.5	20.9
12	.5	1.5	1.6	7.5	21.4	17.5	22.1
13	.6	2.1	1.7	12.3	23.2	19.7	23.4
14	.7	2.8	1.7	17.5	25.2	22.0	24.9
15	.9	3.5	1.8	23.0	27.3	24.6	26.4
16	1.1	4.3	1.9	29.0	29.5	27.3	28.1
17	1.2	5.1	2.0	35.3	31.9	30.1	29.8
18	1.4	6.0	2.0	42.0	34.4	33.2	31.7
19	1.6	6.9	2.1	49.1	37.1	36.4	33.7
20	1.8	7.8	2.2	56.6	39.9	39.8	35.7
21	2.0	8.8	2.3	64.5	42.8	43.4	37.9
22	2.3	9.9	2.4	72.8	45.9	47.2	40.2

TREE GRADE 3
2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
10	0.1	0.5	1.5	4.2	26.2	24.0	23.5
11	.2	1.1	1.6	8.3	28.6	25.4	24.5
12	.4	1.8	1.6	12.7	31.3	26.9	25.5
13	.6	2.6	1.7	17.5	34.3	28.5	26.5
14	.8	3.4	1.7	22.7	37.4	30.3	27.7
15	1.0	4.3	1.8	28.2	40.8	32.2	29.0

CONTINUED

Table 14.—Continued: YELLOW BIRCH

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
16	1.3	5.2	1.9	34.2	44.4	34.2	30.3
17	1.5	6.3	2.0	40.5	48.3	36.4	31.8
18	1.8	7.3	2.0	47.2	52.4	38.6	33.3
19	2.1	8.5	2.1	54.3	56.7	41.1	34.9
20	2.4	9.6	2.2	61.8	61.3	43.6	36.6
21	2.7	10.9	2.3	69.7	66.1	46.3	38.4
22	3.0	12.2	2.4	78.0	71.1	49.1	40.2
23	3.4	13.6	2.5	86.6	76.4	52.0	42.2
24	3.7	15.0	2.6	95.6	81.9	55.1	44.2
TREE GRADE 3 2-1/2 LOGS							
12	0.4	2.1	1.6	17.9	41.2	36.3	28.8
13	.6	3.0	1.7	22.7	45.3	37.4	29.6
14	.9	4.0	1.7	27.9	49.6	38.5	30.6
15	1.2	5.1	1.8	33.4	54.3	39.8	31.5
16	1.5	6.2	1.9	39.4	59.4	41.1	32.6
17	1.8	7.4	2.0	45.7	64.7	42.6	33.7
18	2.2	8.7	2.0	52.4	70.4	44.1	34.9
19	2.6	10.0	2.1	59.5	76.4	45.7	36.1
20	3.0	11.5	2.2	67.0	82.7	47.4	37.5
21	3.4	12.9	2.3	74.9	89.3	49.2	38.8
22	3.8	14.5	2.4	83.2	96.3	51.0	40.3
23	4.3	16.2	2.5	91.8	103.6	53.0	41.8
24	4.7	17.9	2.6	100.8	111.2	55.0	43.4

Table 15.—Lumber grade volume for RED MAPLE

[In board feet]

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2A	No. 2B	No. 3A	No. 3B
TREE GRADE 1 2 LOGS								
16	29.2	21.6	11.3	26.2	36.1	42.7	14.6	2.9
17	32.4	26.3	11.2	34.8	41.1	42.7	14.6	4.0
18	35.8	31.3	11.2	44.0	46.3	42.7	14.6	5.1
19	39.5	36.5	11.1	53.7	51.9	42.7	14.6	6.3
20	43.3	42.1	11.1	63.8	57.7	42.7	14.6	7.6
21	47.3	48.0	11.0	74.6	63.9	42.7	14.6	8.9
22	51.5	54.1	11.0	85.8	70.4	42.7	14.6	10.3
23	55.9	60.5	10.9	97.5	77.1	42.7	14.6	11.7
24	60.5	67.2	10.9	109.8	84.2	42.7	14.6	13.3
25	65.3	74.2	10.8	122.6	91.6	42.7	14.6	14.9
26	70.3	81.5	10.7	136.0	99.2	42.7	14.6	16.5
TREE GRADE 1 2-1/2 LOGS								
16	30.2	29.6	11.7	30.5	45.9	47.5	19.0	6.5
17	36.9	34.1	12.5	39.1	50.3	47.5	19.0	7.6
18	44.0	38.8	13.2	48.2	54.9	47.5	19.0	8.8
19	51.5	43.8	14.1	57.8	59.9	47.5	19.0	10.1
20	59.4	49.0	14.9	68.0	65.0	47.5	19.0	11.4
21	67.7	54.6	15.8	78.7	70.5	47.5	19.0	12.7
22	76.4	60.4	16.8	89.9	76.2	47.5	19.0	14.2
23	85.5	66.4	17.8	101.6	82.2	47.5	19.0	15.7
24	95.0	72.8	18.8	113.8	88.5	47.5	19.0	17.3
25	105.0	79.4	19.9	126.6	95.0	47.5	19.0	18.9
26	115.3	86.2	21.0	139.9	101.8	47.5	19.0	20.6
TREE GRADE 1 3 LOGS								
16	31.3	37.7	12.2	34.8	55.6	52.4	23.5	10.2
17	41.4	41.9	13.7	43.3	59.5	52.4	23.5	11.3
18	52.1	46.3	15.3	52.4	63.5	52.4	23.5	12.5
19	63.5	51.0	17.0	62.0	67.8	52.4	23.5	13.8
20	75.5	56.0	18.8	72.1	72.4	52.4	23.5	15.2
21	88.1	61.2	20.6	82.8	77.1	52.4	23.5	16.6
22	101.3	66.6	22.6	93.9	82.1	52.4	23.5	18.1
23	115.1	72.3	24.6	105.6	87.3	52.4	23.5	19.6
24	129.5	78.3	26.8	117.8	92.8	52.4	23.5	21.3
25	144.6	84.5	29.0	130.5	98.5	52.4	23.5	22.9
26	160.2	90.9	31.4	143.8	104.4	52.4	23.5	24.7
TREE GRADE 1 3-1/2 LOGS								
16	32.3	45.8	12.6	39.0	65.4	57.3	27.9	13.8
17	45.9	49.7	14.9	47.6	68.7	57.3	27.9	15.0
18	60.3	53.9	17.3	56.6	72.1	57.3	27.9	16.2
19	75.5	58.3	19.9	66.2	75.8	57.3	27.9	17.6
20	91.6	62.9	22.6	76.3	79.7	57.3	27.9	18.9
21	108.4	67.8	25.4	86.9	83.7	57.3	27.9	20.4
22	126.1	72.9	28.4	98.0	88.0	57.3	27.9	22.0
23	144.7	78.2	31.5	109.7	92.4	57.3	27.9	23.6
24	164.0	83.8	34.8	121.8	97.1	57.3	27.9	25.2
25	184.2	89.6	38.1	134.5	101.9	57.3	27.9	27.0
26	205.2	95.6	41.7	147.7	107.0	57.3	27.9	28.8

CONTINUED

Table 15.—Continued: RED MAPLE

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2A	No. 2B	No. 3A	No. 3B
TREE GRADE 1 4 LOGS								
16	33.3	53.9	13.1	43.3	75.2	62.2	32.3	17.4
17	50.4	57.6	16.1	51.8	77.9	62.2	32.3	18.7
18	68.4	61.4	19.4	60.8	80.8	62.2	32.3	19.9
19	87.5	65.5	22.8	70.4	83.8	62.2	32.3	21.3
20	107.7	69.8	26.4	80.4	87.0	62.2	32.3	22.7
21	128.8	74.4	30.2	91.0	90.3	62.2	32.3	24.3
22	151.0	79.1	34.2	102.1	93.8	62.2	32.3	25.8
23	174.2	84.1	38.4	113.7	97.5	62.2	32.3	27.5
24	198.5	89.3	42.7	125.8	101.4	62.2	32.3	29.2
25	223.8	94.7	47.3	138.4	105.4	62.2	32.3	31.0
26	250.1	100.3	52.0	151.6	109.6	62.2	32.3	32.9
TREE GRADE 2 2 LOGS								
13	5.6	12.4	7.8	14.4	38.7	44.1	10.5	0.0
14	8.4	14.6	8.1	20.0	41.7	44.4	11.4	.9
15	11.4	16.9	8.4	26.0	44.9	44.6	12.5	3.5
16	14.7	19.4	8.8	32.4	48.3	44.8	13.6	6.3
17	18.1	22.0	9.2	39.2	51.9	45.1	14.7	9.3
18	21.7	24.8	9.6	46.4	55.8	45.4	16.0	12.4
19	25.5	27.8	10.0	54.1	59.9	45.7	17.3	15.8
20	29.6	30.9	10.5	62.1	64.1	46.0	18.7	19.3
21	33.8	34.2	11.0	70.6	68.7	46.4	20.1	23.0
22	38.2	37.6	11.5	79.4	73.4	46.7	21.6	26.9
23	42.9	41.2	12.0	88.7	78.3	47.1	23.2	30.9
24	47.8	45.0	12.6	98.4	83.5	47.5	24.9	35.1
TREE GRADE 2 2-1/2 LOGS								
13	2.9	11.3	8.6	17.8	53.1	49.7	13.0	0.6
14	7.7	14.8	9.2	23.3	55.1	49.9	14.0	2.8
15	12.9	18.5	9.8	29.2	57.2	50.1	15.0	5.2
16	18.4	22.4	10.4	35.6	59.5	50.4	16.1	7.7
17	24.3	26.7	11.1	42.3	61.9	50.7	17.2	10.4
18	30.5	31.1	11.8	49.4	64.4	50.9	18.5	13.2
19	37.1	35.9	12.5	57.0	67.1	51.2	19.8	16.3
20	44.1	40.9	13.3	64.9	69.9	51.6	21.2	19.4
21	51.4	46.1	14.1	73.3	72.9	51.9	22.6	22.8
22	59.1	51.6	15.0	82.0	76.0	52.3	24.2	26.3
23	67.2	57.4	15.9	91.2	79.3	52.6	25.8	29.9
24	75.5	63.4	16.8	100.8	82.7	53.0	27.4	33.7
TREE GRADE 2 3 LOGS								
13	0.1	10.2	9.5	21.2	67.5	55.2	15.5	2.8
14	6.9	14.9	10.3	26.7	68.5	55.4	16.5	4.7
15	14.3	20.0	11.1	32.5	69.5	55.7	17.5	6.9
16	22.1	25.5	12.0	38.7	70.6	55.9	18.6	9.1
17	30.5	31.3	12.9	45.4	71.8	56.2	19.8	11.5
18	39.4	37.5	13.9	52.4	73.0	56.5	21.0	14.0
19	48.8	44.0	15.0	59.9	74.3	56.8	22.3	16.7
20	58.7	50.8	16.1	67.7	75.7	57.1	23.7	19.6
21	69.1	58.1	17.3	76.0	77.2	57.4	25.2	22.5
22	80.0	65.6	18.5	84.6	78.7	57.8	26.7	25.7
23	91.4	73.5	19.8	93.7	80.3	58.2	28.3	28.9
24	103.3	81.8	21.1	103.1	81.9	58.6	29.9	32.3
TREE GRADE 3 1 LOG								
10	0.0	0.1	0.0	0.0	3.8	18.9	4.7	1.9
11	.5	.3	.0	3.7	5.9	19.5	5.8	2.9

CONTINUED

Table 15.—Continued: RED MAPLE

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2A	No. 2B	No. 3A	No. 3B
12	1.2	.6	.1	8.0	8.3	20.1	7.0	4.0
13	2.0	.8	.6	12.7	10.9	20.7	8.3	5.1
14	2.9	1.1	1.2	17.8	13.7	21.4	9.8	6.4
15	3.8	1.5	1.9	23.2	16.7	22.2	11.3	7.8
16	4.8	1.8	2.6	29.0	19.9	23.0	12.9	9.3
17	5.8	2.2	3.3	35.2	23.3	23.9	14.6	10.8
18	6.9	2.6	4.1	41.8	26.9	24.8	16.4	12.5
19	8.1	3.0	4.9	48.8	30.7	25.8	18.4	14.3
20	9.4	3.4	5.8	56.1	34.8	26.8	20.4	16.1
TREE GRADE 3 1-1/2 LOGS								
10	0.0	0.3	1.6	0.7	11.1	32.4	5.8	1.9
11	.6	1.0	2.0	4.6	13.7	32.9	7.0	2.9
12	1.4	1.8	2.4	9.0	16.6	33.5	8.2	4.0
13	2.2	2.7	2.9	13.7	19.7	34.2	9.6	5.1
14	3.0	3.6	3.3	18.7	23.1	34.9	11.0	6.4
15	3.9	4.7	3.8	24.2	26.7	35.7	12.6	7.8
16	4.9	5.7	4.4	30.0	30.5	36.5	14.3	9.3
17	6.0	6.9	5.0	36.2	34.6	37.3	16.1	10.8
18	7.1	8.1	5.6	42.8	39.0	38.3	17.9	12.5
19	8.2	9.4	6.2	49.7	43.6	39.2	19.9	14.3
20	9.5	10.7	6.9	57.1	48.5	40.3	22.1	16.1
TREE GRADE 3 2 LOGS								
10	0.1	0.5	4.2	1.7	18.5	45.8	7.0	1.9
11	.8	1.8	4.5	5.6	21.5	46.4	8.1	2.9
12	1.5	3.1	4.8	9.9	24.9	47.0	9.4	4.0
13	2.3	4.6	5.1	14.6	28.5	47.6	10.8	5.1
14	3.1	6.1	5.4	19.7	32.5	48.4	12.3	6.4
15	4.1	7.8	5.8	25.1	36.7	49.1	13.9	7.8
16	5.0	9.7	6.2	31.0	41.2	49.9	15.7	9.3
17	6.1	11.6	6.7	37.2	46.0	50.8	17.5	10.8
18	7.2	13.6	7.1	43.7	51.1	51.7	19.5	12.5
19	8.4	15.8	7.6	50.7	56.5	52.7	21.5	14.3
20	9.6	18.1	8.1	58.0	62.1	53.7	23.7	16.1
TREE GRADE 3 2-1/2 LOGS								
10	0.2	0.8	6.8	2.6	25.9	59.3	8.1	1.9
11	.9	2.5	6.9	6.6	29.4	59.8	9.3	2.9
12	1.6	4.4	7.1	10.9	33.2	60.4	10.6	4.0
13	2.4	6.4	7.3	15.6	37.4	61.1	12.0	5.1
14	3.3	8.6	7.6	20.7	41.9	61.8	13.6	6.4
15	4.2	11.0	7.8	26.1	46.7	62.6	15.3	7.8
16	5.2	13.6	8.1	31.9	51.8	63.4	17.1	9.3
17	6.2	16.3	8.3	38.1	57.3	64.2	19.0	10.8
18	7.3	19.2	8.6	44.7	63.2	65.2	21.0	12.5
19	8.5	22.2	8.9	51.7	69.3	66.1	23.1	14.3
20	9.7	25.4	9.3	59.0	75.8	67.2	25.4	16.1
TREE GRADE 3 3 LOGS								
10	0.3	1.0	9.3	3.6	33.2	72.7	9.2	1.9
11	1.0	3.2	9.4	7.5	37.2	73.3	10.4	2.9
12	1.7	5.6	9.5	11.9	41.5	73.9	11.8	4.0
13	2.5	8.3	9.6	16.6	46.2	74.6	13.3	5.1
14	3.4	11.2	9.7	21.6	51.2	75.3	14.9	6.4
15	4.3	14.2	9.8	27.1	56.7	76.0	16.6	7.8
16	5.3	17.5	9.9	32.9	62.5	76.8	18.4	9.3
17	6.3	21.0	10.0	39.1	68.7	77.7	20.4	10.8
18	7.5	24.7	10.2	45.7	75.3	78.6	22.5	12.5
19	8.6	28.6	10.3	52.6	82.2	79.6	24.7	14.3
20	9.9	32.8	10.4	60.0	89.5	80.6	27.0	16.1

Table 16.—Lumber grade volume for BLACK OAK

[In board feet]

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
TREE GRADE 1 2 LOGS								
16	0.0	16.7	1.9	36.4	41.8	12.2	52.4	17.2
17	.0	20.1	2.9	46.0	45.3	12.2	53.2	18.0
18	4.4	23.7	3.9	56.3	49.1	12.2	54.0	18.8
19	11.8	27.6	5.0	67.1	53.0	12.2	54.9	19.6
20	19.6	31.7	6.2	78.5	57.2	12.2	55.8	20.5
21	27.7	35.9	7.4	90.5	61.6	12.2	56.8	21.4
22	36.3	40.4	8.7	103.1	66.2	12.2	57.8	22.4
23	45.2	45.1	10.0	116.2	71.0	12.2	58.9	23.4
24	54.6	50.0	11.4	130.0	76.0	12.2	60.0	24.5
25	64.3	55.1	12.8	144.3	81.3	12.2	61.2	25.6
26	74.5	60.4	14.3	159.3	86.7	12.2	62.4	26.7
TREE GRADE 1 2-1/2 LOGS								
16	0.0	14.2	1.9	45.3	59.4	16.5	64.4	35.5
17	2.1	18.5	2.9	56.4	62.9	16.5	65.2	36.2
18	9.7	23.0	3.9	68.2	66.7	16.5	66.1	37.0
19	17.6	27.9	5.0	80.7	70.6	16.5	67.0	37.9
20	26.0	32.9	6.2	93.9	74.8	16.5	67.9	38.7
21	34.8	38.3	7.4	107.7	79.2	16.5	68.9	39.7
22	44.1	43.9	8.7	122.2	83.8	16.5	69.9	40.7
23	53.7	49.7	10.0	137.4	88.6	16.5	71.0	41.7
24	63.9	55.8	11.4	153.2	93.7	16.5	72.1	42.7
25	74.4	62.2	12.8	169.8	98.9	16.5	73.3	43.8
26	85.4	68.9	14.3	187.0	104.4	16.5	74.5	45.0
27	96.7	75.8	15.9	204.9	110.0	16.5	75.8	46.2
28	108.6	82.9	17.5	223.4	115.9	16.5	77.1	47.4
29	120.8	90.3	19.2	242.7	122.0	16.5	78.4	48.7
30	133.5	98.0	21.0	262.6	128.3	16.5	79.9	50.1
TREE GRADE 1 3 LOGS								
16	0.0	11.7	1.9	54.2	77.0	20.9	76.5	53.7
17	6.8	16.9	2.9	66.8	80.5	20.9	77.3	54.5
18	14.9	22.4	3.9	80.2	84.3	20.9	78.2	55.3
19	23.4	28.1	5.0	94.3	88.2	20.9	79.0	56.1
20	32.5	34.2	6.2	109.2	92.4	20.9	80.0	57.0
21	41.9	40.6	7.4	124.9	96.8	20.9	81.0	57.9
22	51.9	47.3	8.7	141.3	101.4	20.9	82.0	58.9
23	62.3	54.4	10.0	158.5	106.2	20.9	83.1	59.9
24	73.1	61.7	11.4	176.5	111.3	20.9	84.2	61.0
25	84.5	69.4	12.8	195.2	116.5	20.9	85.4	62.1
26	96.3	77.3	14.3	214.7	122.0	20.9	86.6	63.3
27	108.5	85.6	15.9	235.0	127.7	20.9	87.8	64.5
28	121.2	94.2	17.5	256.0	133.5	20.9	89.2	65.7
29	134.4	103.1	19.2	277.8	139.6	20.9	90.5	67.0
30	148.0	112.3	21.0	300.3	146.0	20.9	91.9	68.3
31	162.1	121.9	22.8	323.6	152.5	20.9	93.4	69.7
32	176.7	131.7	24.6	347.7	159.2	20.9	94.9	71.1
33	191.7	141.8	26.6	372.6	166.2	20.9	96.5	72.6
34	207.2	152.3	28.5	398.2	173.4	20.9	98.1	74.1
TREE GRADE 1 3-1/2 LOGS								
16	3.3	9.3	1.9	63.1	94.6	25.3	88.6	72.0
17	11.5	15.3	2.9	77.2	98.1	25.3	89.4	72.7
18	20.1	21.7	3.9	92.1	101.9	25.3	90.2	73.5

CONTINUED

Table 16.—Continued: BLACK OAK

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
19	29.3	28.4	5.0	107.9	105.9	25.3	91.1	74.4
20	38.9	35.5	6.2	124.6	110.0	25.3	92.1	75.3
21	49.0	43.0	7.4	142.1	114.4	25.3	93.0	76.2
22	59.7	50.8	8.7	160.4	119.0	25.3	94.1	77.2
23	70.8	59.0	10.0	179.7	123.8	25.3	95.1	78.2
24	82.4	67.6	11.4	199.7	128.9	25.3	96.3	79.2
25	94.5	76.5	12.8	220.7	134.1	25.3	97.4	80.4
26	107.2	85.8	14.3	242.4	139.6	25.3	98.7	81.5
27	120.3	95.5	15.9	265.1	145.3	25.3	99.9	82.7
28	133.9	105.5	17.5	288.5	151.2	25.3	101.2	84.0
29	148.0	115.9	19.2	312.9	157.3	25.3	102.6	85.3
30	162.5	126.6	21.0	338.1	163.6	25.3	104.0	86.6
31	177.6	137.7	22.8	364.1	170.1	25.3	105.5	88.0
32	193.2	149.2	24.6	391.0	176.9	25.3	107.0	89.4
33	209.3	161.1	26.6	418.8	183.8	25.3	108.5	90.9
34	225.9	173.3	28.5	447.4	191.0	25.3	110.1	92.4

TREE GRADE 2
1-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
13	0.0	3.3	0.0	0.0	18.4	1.5	29.2	28.2
14	1.9	5.9	.0	.0	22.0	1.5	30.2	27.4
15	4.8	8.6	.0	7.7	25.9	1.5	31.2	26.4
16	7.9	11.6	.0	19.5	30.1	1.5	32.3	25.5
17	11.2	14.8	.2	31.9	34.5	1.5	33.5	24.4
18	14.7	18.1	.8	45.2	39.2	1.5	34.7	23.3
19	18.4	21.7	1.5	59.2	44.1	1.5	36.0	22.1
20	22.3	25.4	2.2	73.9	49.3	1.5	37.4	20.9
21	26.4	29.4	2.9	89.4	54.8	1.5	38.8	19.6
22	30.7	33.5	3.6	105.7	60.6	1.5	40.3	18.2
23	35.2	37.8	4.4	122.7	66.6	1.5	41.9	16.8
24	39.9	42.3	5.3	140.5	72.9	1.5	43.6	15.3

TREE GRADE 2
2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
13	0.0	1.5	0.7	0.0	24.9	6.6	38.2	36.6
14	1.9	4.3	1.1	4.2	29.6	6.6	39.5	35.8
15	4.8	7.4	1.5	15.9	34.6	6.6	40.9	35.1
16	7.9	10.7	1.9	28.5	40.0	6.6	42.4	34.3
17	11.2	14.2	2.3	41.8	45.8	6.6	44.0	33.4
18	14.7	17.9	2.7	56.0	51.8	6.6	45.6	32.5
19	18.4	21.9	3.2	70.9	58.3	6.6	47.4	31.5
20	22.3	26.0	3.7	86.7	65.1	6.6	49.3	30.5
21	26.4	30.4	4.3	103.3	72.2	6.6	51.2	29.4
22	30.7	34.9	4.8	120.6	79.7	6.6	53.3	28.3
23	35.2	39.7	5.4	138.8	87.5	6.6	55.4	27.1
24	39.9	44.7	6.0	157.8	95.7	6.6	57.7	25.8
25	44.7	49.9	6.7	177.6	104.2	6.6	60.0	24.6
26	49.8	55.3	7.3	198.3	113.1	6.6	62.5	23.2
27	55.1	60.9	8.0	219.7	122.3	6.6	65.0	21.8
28	60.6	66.8	8.7	241.9	131.9	6.6	67.6	20.4

TREE GRADE 2
2-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
13	0.0	0.0	3.3	0.0	31.3	11.6	47.2	44.9
14	1.9	2.8	3.6	11.7	37.1	11.6	48.8	44.3
15	4.8	6.2	3.8	24.1	43.3	11.6	50.6	43.7
16	7.9	9.8	4.1	37.5	50.0	11.6	52.5	43.1
17	11.2	13.6	4.4	51.7	57.0	11.6	54.4	42.4
18	14.7	17.7	4.7	66.7	64.5	11.6	56.6	41.7
19	18.4	22.0	5.0	82.7	72.5	11.6	58.8	40.9
20	22.3	26.6	5.3	99.4	80.8	11.6	61.1	40.1
21	26.4	31.3	5.6	117.1	89.6	11.6	63.6	39.2
22	30.7	36.3	6.0	135.6	98.8	11.6	66.2	38.3
23	35.2	41.6	6.4	154.9	108.4	11.6	68.9	37.4

CONTINUED

Table 16.—Continued: BLACK OAK

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
24	39.9	47.0	6.8	175.2	118.5	11.6	71.8	36.4
25	44.7	52.7	7.2	196.3	129.0	11.6	74.7	35.4
26	49.8	58.7	7.6	218.2	139.9	11.6	77.8	34.3
27	55.1	64.8	8.1	241.0	151.3	11.6	81.0	33.2
28	60.6	71.2	8.5	264.7	163.1	11.6	84.3	32.0
				TREE GRADE 2 3 LOGS				
13	0.0	0.0	6.0	6.8	37.8	16.6	56.2	53.3
14	1.9	1.3	6.1	19.1	44.7	16.6	58.1	52.8
15	4.8	5.0	6.2	32.3	52.0	16.6	60.3	52.4
16	7.9	8.9	6.3	46.5	59.9	16.6	62.5	51.9
17	11.2	13.1	6.4	61.5	68.3	16.6	64.9	51.4
18	14.7	17.5	6.6	77.5	77.2	16.6	67.5	50.8
19	18.4	22.2	6.7	94.4	86.6	16.6	70.2	50.3
20	22.3	27.1	6.9	112.2	96.5	16.6	73.0	49.7
21	26.4	32.3	7.0	130.9	107.0	16.6	76.0	49.0
22	30.7	37.7	7.2	150.5	117.9	16.6	79.2	48.4
23	35.2	43.4	7.4	171.1	129.4	16.6	82.5	47.7
24	39.9	49.4	7.5	192.5	141.3	16.6	85.9	46.9
25	44.7	55.6	7.7	214.9	153.8	16.6	89.5	46.2
26	49.8	62.0	7.9	238.1	166.7	16.6	93.2	45.4
27	55.1	68.7	8.1	262.3	180.2	16.6	97.0	44.5
28	60.6	75.7	8.3	287.4	194.2	16.6	101.1	43.7
29	66.3	82.9	8.6	313.4	208.7	16.6	105.2	42.8
30	72.2	90.4	8.8	340.4	223.7	16.6	109.5	41.9
				TREE GRADE 3 1 LOG				
10	0.0	0.0	1.0	0.0	1.6	3.5	9.2	14.5
11	.0	.0	1.0	.0	4.7	4.0	12.1	12.0
12	.2	.0	.9	5.5	8.1	4.7	15.4	9.3
13	.6	1.6	.9	12.7	11.7	5.3	18.9	6.3
14	1.1	3.6	.9	20.4	15.7	6.0	22.7	3.1
15	1.5	5.8	.8	28.7	20.0	6.8	26.7	.0
16	2.0	8.1	.8	37.6	24.5	7.6	31.1	.0
				TREE GRADE 3 1-1/2 LOGS				
10	0.0	0.0	0.2	0.0	11.7	8.2	20.7	28.7
11	.0	.0	.3	.0	14.7	8.5	22.9	27.4
12	.0	.0	.4	5.5	18.1	8.9	25.4	25.9
13	.4	1.6	.5	12.7	21.7	9.3	28.0	24.3
14	1.2	3.6	.7	20.4	25.7	9.8	30.9	22.6
15	2.1	5.8	.8	28.7	29.9	10.3	33.9	20.7
16	3.0	8.1	1.0	37.6	34.4	10.8	37.2	18.7
17	3.9	10.5	1.2	47.1	39.2	11.3	40.7	16.6
18	5.0	13.2	1.4	57.1	44.3	11.9	44.4	14.4
19	6.0	15.9	1.6	67.8	49.7	12.6	48.3	12.0
20	7.2	18.8	1.8	78.9	55.4	13.2	52.4	9.5

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Table 16.—Continued: BLACK OAK

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
TREE GRADE 3 2 LOGS								
12	0.0	0.0	0.0	5.5	28.1	13.2	35.4	42.5
13	.2	1.6	.2	12.7	31.7	13.4	37.2	42.3
14	1.3	3.6	.5	20.4	35.6	13.5	39.1	42.0
15	2.6	5.8	.8	28.7	39.8	13.7	41.1	41.8
16	3.9	8.1	1.2	37.6	44.2	13.9	43.3	41.5
17	5.3	10.5	1.6	47.1	49.0	14.2	45.7	41.2
18	6.8	13.2	2.0	57.1	54.0	14.4	48.1	40.8
19	8.4	15.9	2.4	67.8	59.4	14.7	50.8	40.5
20	10.0	18.8	2.9	78.9	65.0	14.9	53.5	40.1
21	11.8	21.9	3.4	90.7	70.9	15.2	56.4	39.7
22	13.6	25.1	3.9	103.1	77.1	15.5	59.5	39.3
23	15.5	28.5	4.4	116.0	83.6	15.8	62.7	38.9
24	17.5	32.0	5.0	129.5	90.4	16.1	66.0	38.4
TREE GRADE 3 2-1/2 LOGS								
16	4.8	8.1	1.4	37.6	54.1	17.1	49.5	64.2
17	6.7	10.5	2.0	47.1	58.8	17.0	50.6	65.7
18	8.6	13.2	2.7	57.1	63.8	16.9	51.9	67.2
19	10.7	15.9	3.3	67.8	69.1	16.8	53.2	68.9
20	12.9	18.8	4.1	78.9	74.6	16.6	54.6	70.6
21	15.2	21.9	4.8	90.7	80.5	16.5	56.1	72.5
22	17.6	25.1	5.6	103.1	86.6	16.4	57.7	74.4
23	20.1	28.5	6.4	116.0	93.0	16.3	59.3	76.4
24	22.7	32.0	7.3	129.5	99.7	16.1	61.0	78.5
25	25.5	35.6	8.2	143.5	106.7	16.0	62.7	80.7
26	28.3	39.5	9.1	158.2	114.0	15.8	64.6	83.0
27	31.3	43.4	10.1	173.4	121.5	15.6	66.5	85.4
28	34.3	47.5	11.1	189.2	129.3	15.5	68.5	87.8

Table 17.—Lumber grade volume for BASSWOOD

[In board feet]

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3C
TREE GRADE 1 1-1/2 LOGS					
15	25.0	37.9	26.1	48.1	0.0
16	26.3	39.1	30.7	55.7	4.6
17	27.6	40.3	35.5	63.8	12.3
18	28.9	41.6	40.7	72.3	20.5
19	30.4	43.0	46.2	81.4	29.1
20	31.9	44.5	52.0	90.9	38.2
TREE GRADE 1 2 LOGS					
15	18.4	39.2	37.0	59.5	3.6
16	22.9	41.3	41.5	66.7	9.9
17	27.8	43.6	46.2	74.4	16.6
18	33.0	45.9	51.3	82.6	23.7
19	38.4	48.5	56.6	91.3	31.3
20	44.2	51.1	62.2	100.4	39.2
TREE GRADE 1 2-1/2 LOGS					
15	11.7	40.5	47.9	70.8	9.9
16	19.6	43.6	52.3	77.7	15.2
17	28.1	46.8	56.9	85.1	21.0
18	37.0	50.2	61.8	92.9	27.0
19	46.5	53.9	67.0	101.1	33.4
20	56.4	57.7	72.4	109.8	40.2
21	66.9	61.8	78.2	118.9	47.2
22	77.9	66.0	84.2	128.5	54.7
23	89.4	70.4	90.5	138.5	62.5
24	101.4	75.0	97.1	149.0	70.6
TREE GRADE 1 3 LOGS					
15	5.0	41.8	58.8	82.2	16.1
16	16.3	45.8	63.1	88.7	20.6
17	28.3	50.0	67.6	95.7	25.3
18	41.0	54.5	72.3	103.1	30.3
19	54.5	59.3	77.4	111.0	35.6
20	68.7	64.3	82.7	119.2	41.1
21	83.6	69.6	88.3	127.9	47.0
22	99.2	75.2	94.1	137.0	53.2
23	115.6	81.0	100.3	146.6	59.6
24	132.7	87.0	106.7	156.5	66.3
25	150.5	93.3	113.3	166.9	73.3
26	169.0	99.9	120.3	177.7	80.6
TREE GRADE 1 3-1/2 LOGS					
15	0.0	43.1	69.8	93.5	22.4
16	13.0	48.0	73.9	99.8	25.9
17	28.6	53.3	78.2	106.4	29.6
18	45.1	58.8	82.9	113.4	33.5
19	62.5	64.7	87.8	120.8	37.7
20	80.9	71.0	92.9	128.7	42.1
21	100.3	77.5	98.3	136.9	46.8
22	120.6	84.3	104.0	145.6	51.6
23	141.8	91.5	110.0	154.6	56.7
24	164.0	99.0	116.2	164.0	62.0
25	187.1	106.8	122.7	173.9	67.5
26	211.1	114.9	129.5	184.1	73.3

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Table 17.—Continued: BASSWOOD

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3C
		TREE GRADE 1 4 LOGS			
15	0.0	44.4	80.7	104.9	28.6
16	9.7	50.2	84.7	110.8	31.2
17	28.8	56.5	88.9	117.0	33.9
18	49.1	63.1	93.4	123.7	36.8
19	70.6	70.2	98.1	130.7	39.9
20	93.2	77.6	103.2	138.1	43.1
21	116.9	85.3	108.4	145.9	46.5
22	141.9	93.5	113.9	154.1	50.1
23	168.0	102.0	119.7	162.6	53.8
24	195.2	111.0	125.8	171.5	57.7
25	223.7	120.3	132.1	180.8	61.8
26	253.2	129.9	138.6	190.5	66.0
		TREE GRADE 2 1-1/2 LOGS			
13	5.1	9.3	9.8	45.1	11.9
14	5.2	12.5	13.9	47.9	14.3
15	5.4	16.0	18.4	50.9	17.0
16	5.5	19.7	23.1	54.2	19.8
17	5.7	23.7	28.1	57.6	22.7
18	5.9	27.9	33.5	61.3	25.9
19	6.1	32.3	39.2	65.1	29.2
20	6.3	37.0	45.1	69.2	32.8
		TREE GRADE 2 2 LOGS			
13	3.5	10.3	26.2	62.6	6.8
14	5.1	14.4	29.9	65.0	10.6
15	6.7	18.9	33.9	67.7	14.7
16	8.4	23.6	38.2	70.6	19.1
17	10.2	28.6	42.7	73.6	23.7
18	12.2	34.0	47.6	76.9	28.7
19	14.3	39.6	52.7	80.3	33.9
20	16.4	45.6	58.0	83.9	39.4
21	18.7	51.8	63.7	87.6	45.2
22	21.1	58.4	69.6	91.6	51.3
		TREE GRADE 2 2-1/2 LOGS			
13	2.0	11.3	42.6	80.1	1.7
14	4.9	16.3	46.0	82.2	6.9
15	8.0	21.7	49.5	84.5	12.5
16	11.3	27.5	53.3	87.0	18.4
17	14.8	33.6	57.3	89.6	24.8
18	18.5	40.1	61.6	92.4	31.5
19	22.5	47.0	66.2	95.4	38.6
20	26.6	54.2	70.9	98.5	46.1
21	31.0	61.8	76.0	101.8	54.0
22	35.6	69.8	81.2	105.2	62.2
		TREE GRADE 2 3 LOGS			
16	14.2	31.3	68.4	103.4	17.7
17	19.4	38.5	71.9	105.7	25.8
18	24.9	46.2	75.7	108.0	34.3
19	30.7	54.3	79.7	110.5	43.3
20	36.8	62.8	83.8	113.1	52.7
21	43.2	71.7	88.2	115.9	62.7
22	50.0	81.1	92.9	118.8	73.2
23	57.1	91.0	97.7	121.9	84.1

CONTINUED

Table 17.—Continued: BASSWOOD

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3C
TREE GRADE 2 3-1-2 LOGS					
16	17.1	35.2	83.5	119.9	17.1
17	23.9	43.5	86.5	121.7	26.8
18	31.2	52.3	89.8	123.6	37.1
19	38.9	61.6	93.2	125.6	47.9
20	47.0	71.4	96.7	127.8	59.4
21	55.5	81.7	100.5	130.0	71.5
22	64.4	92.5	104.5	132.4	84.1
23	73.8	103.8	108.6	134.9	97.3
TREE GRADE 3 1 LOG					
10	0.0	2.9	0.0	15.2	11.5
11	.0	2.6	.9	20.6	12.4
12	.0	2.3	3.7	26.5	13.3
13	.0	2.0	6.6	32.9	14.3
14	.0	1.6	9.9	39.9	15.3
15	.0	1.2	13.3	47.3	16.5
16	.0	.8	17.0	55.3	17.7
17	.4	.4	20.9	63.8	19.0
18	.8	.0	25.0	72.8	20.4
TREE GRADE 3 1-1/2 LOGS					
10	0.0	3.0	5.6	26.0	10.8
11	.1	3.3	8.1	31.6	12.2
12	.5	3.7	10.8	37.8	13.8
13	.8	4.2	13.8	44.5	15.5
14	1.2	4.7	17.0	51.7	17.3
15	1.6	5.2	20.4	59.5	19.3
16	2.0	5.7	24.1	67.8	21.4
17	2.5	6.3	28.0	76.7	23.7
18	3.0	6.9	32.2	86.1	26.1
19	3.5	7.6	36.6	96.0	28.6
20	4.0	8.3	41.2	106.4	31.2
21	4.6	9.0	46.1	117.4	34.0
22	5.2	9.7	51.2	129.0	37.0
23	5.8	10.5	56.5	141.1	40.0
TREE GRADE 3 2 LOGS					
10	1.3	3.0	12.7	36.7	10.0
11	1.7	4.0	15.2	42.6	12.1
12	2.1	5.2	18.0	49.0	14.3
13	2.5	6.4	20.9	56.0	16.7
14	3.0	7.7	24.1	63.6	19.3
15	3.5	9.1	27.6	71.7	22.2
16	4.0	10.6	31.3	80.4	25.2
17	4.6	12.2	35.2	89.6	28.3
18	5.2	14.0	39.3	99.4	31.7
19	5.8	15.8	43.7	109.7	35.3
20	6.5	17.7	48.4	120.6	39.1
21	7.2	19.7	53.2	132.1	43.1
22	7.9	21.8	58.3	144.1	47.2
23	8.7	24.0	63.7	156.7	51.6

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Table 17.—Continued: BASSWOOD

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3C
		TREE GRADE 3 2-1/2 LOGS			
10	2.8	3.1	19.9	47.5	9.3
11	3.3	4.7	22.4	53.6	11.9
12	3.7	6.6	25.1	60.3	14.8
13	4.2	8.6	28.1	67.6	18.0
14	4.8	10.7	31.3	75.4	21.3
15	5.4	13.1	34.7	83.9	25.0
16	6.0	15.5	38.4	92.9	28.9
17	6.7	18.2	42.3	102.5	33.0
18	7.4	21.0	46.5	112.7	37.4
19	8.1	23.9	50.9	123.4	42.1
20	8.9	27.1	55.5	134.8	47.0
21	9.8	30.3	60.4	146.7	52.1
22	10.6	33.8	65.5	159.2	57.5
23	11.5	37.4	70.8	172.3	63.1
		TREE GRADE 3 3 LOGS			
10	4.3	3.1	27.0	58.3	8.6
11	4.8	5.4	29.5	64.6	11.8
12	5.4	8.0	32.3	71.6	15.3
13	6.0	10.8	35.2	79.1	19.2
14	6.6	13.8	38.4	87.3	23.4
15	7.3	17.0	41.9	96.1	27.8
16	8.0	20.5	45.5	105.4	32.6
17	8.8	24.1	49.5	115.4	37.7
18	9.6	28.0	53.6	126.0	43.1
19	10.5	32.1	58.0	137.2	48.8
20	11.4	36.5	62.6	148.9	54.8
21	12.3	41.0	67.5	161.3	61.1
22	13.3	45.8	72.6	174.3	67.8
23	14.4	50.8	78.0	187.9	74.7

Table 18.—Lumber grade volume for SUGAR MAPLE

[In board feet]

TREE GRADE 1
1-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
16	4.6	25.0	8.7	39.4	38.0	23.5	21.1
17	8.5	28.2	8.7	44.2	43.6	24.2	24.7
18	12.7	31.5	8.7	49.3	49.4	25.1	28.6
19	17.1	35.0	8.7	54.7	55.7	26.0	32.6
20	21.7	38.8	8.7	60.3	62.2	26.9	36.9
21	26.6	42.7	8.7	66.3	69.1	27.9	41.4

TREE GRADE 1
2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
16	7.0	26.9	8.7	38.3	42.2	27.1	31.0
17	11.7	30.0	8.7	45.7	47.7	28.3	34.1
18	16.8	33.4	8.7	53.4	53.4	29.7	37.3
19	22.1	36.9	8.7	61.6	59.5	31.1	40.8
20	27.7	40.6	8.7	70.3	65.9	32.6	44.4
21	33.5	44.6	8.7	79.4	72.7	34.2	48.2
22	39.7	48.7	8.7	88.9	79.8	35.8	52.2
23	46.2	53.0	8.7	98.9	87.2	37.6	56.4
24	52.9	57.5	8.7	109.4	94.9	39.4	60.7
25	59.9	62.1	8.7	120.2	103.0	41.3	65.3
26	67.3	67.0	8.7	131.6	111.4	43.2	70.0
27	74.9	72.1	8.7	143.3	120.1	45.3	75.0

TREE GRADE 1
2-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
16	9.4	28.7	8.7	37.2	46.4	30.7	40.9
17	14.9	31.9	8.7	47.1	51.8	32.4	43.4
18	20.8	35.2	8.7	57.6	57.4	34.3	46.1
19	27.0	38.8	8.7	68.6	63.4	36.3	48.9
20	33.6	42.5	8.7	80.2	69.7	38.3	51.9
21	40.5	46.4	8.7	92.5	76.3	40.5	55.0
22	47.7	50.5	8.7	105.3	83.2	42.8	58.3
23	55.3	54.8	8.7	118.8	90.5	45.2	61.8
24	63.2	59.3	8.7	132.8	98.1	47.7	65.4
25	71.5	64.0	8.7	147.4	106.0	50.3	69.1
26	80.1	68.9	8.7	162.7	114.2	53.0	73.0
27	89.0	74.0	8.7	178.5	122.8	55.8	77.0
28	98.3	79.2	8.7	194.9	131.6	58.8	81.2
29	107.9	84.7	8.7	211.9	140.8	61.8	85.6
30	117.8	90.3	8.7	229.6	150.4	64.9	90.1

TREE GRADE 1
3 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
16	11.7	30.6	8.7	36.2	50.7	34.3	50.8
17	18.1	33.8	8.7	48.5	55.9	36.5	52.8
18	24.9	37.1	8.7	61.7	61.4	38.9	54.9
19	32.0	40.7	8.7	75.6	67.3	41.4	57.1
20	39.5	44.4	8.7	90.2	73.4	44.0	59.4
21	47.5	48.3	8.7	105.6	79.9	46.8	61.9
22	55.8	52.4	8.7	121.7	86.7	49.8	64.5
23	64.5	56.7	8.7	138.6	93.8	52.8	67.1
24	73.6	61.2	8.7	156.3	101.2	56.0	70.0
25	83.0	65.9	8.7	174.6	109.0	59.3	72.9
26	92.9	70.8	8.7	193.8	117.0	62.8	76.0
27	103.1	75.8	8.7	213.7	125.4	66.4	79.1
28	113.8	81.1	8.7	234.3	134.1	70.2	82.4
29	124.8	86.5	8.7	255.7	143.1	74.0	85.8
30	136.2	92.2	8.7	277.8	152.4	78.0	89.4

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Table 18.—Continued: SUGAR MAPLE

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 1 3-1/2 LOGS							
20	45.5	46.3	8.7	100.2	77.2	49.8	66.9
21	54.4	50.2	8.7	118.7	83.5	53.2	68.7
22	63.8	54.3	8.7	138.1	90.1	56.7	70.6
23	73.6	58.6	8.7	158.5	97.1	60.4	72.5
24	83.9	63.1	8.7	179.7	104.4	64.3	74.6
25	94.6	67.8	8.7	201.8	112.0	68.4	76.7
26	105.7	72.6	8.7	224.9	119.8	72.6	78.9
27	117.2	77.7	8.7	248.9	128.0	77.0	81.2
28	129.2	83.0	8.7	273.7	136.6	81.5	83.6
29	141.7	88.4	8.7	299.5	145.4	86.2	86.1
30	154.5	94.1	8.7	326.1	154.5	91.1	88.6
TREE GRADE 2 1-1/2 LOGS							
13	3.7	3.4	7.6	4.6	19.1	16.4	25.1
14	4.9	6.2	7.6	12.3	23.1	17.2	24.8
15	6.3	9.3	7.6	20.4	27.5	18.0	24.6
16	7.8	12.5	7.6	29.2	32.1	18.9	24.4
17	9.3	15.9	7.6	38.5	37.1	19.9	24.1
18	11.0	19.5	7.6	48.4	42.3	21.0	23.8
19	12.7	23.4	7.6	58.8	47.9	22.1	23.6
20	14.6	27.4	7.6	69.9	53.7	23.2	23.2
21	16.5	31.7	7.6	81.4	59.9	24.5	22.9
22	18.6	36.2	7.6	93.6	66.3	25.7	22.6
23	20.7	40.8	7.6	106.3	73.0	27.1	22.2
24	22.9	45.7	7.6	119.5	80.1	28.5	21.9
25	25.2	50.8	7.6	133.4	87.4	29.9	21.5
26	27.6	56.1	7.6	147.8	95.1	31.4	21.1
27	30.1	61.6	7.6	162.7	103.0	33.0	20.7
TREE GRADE 2 2 LOGS							
13	4.1	7.5	7.6	9.1	28.8	24.3	27.4
14	5.6	10.3	7.6	17.2	32.9	25.2	27.9
15	7.3	13.3	7.6	25.9	37.3	26.2	28.5
16	9.0	16.5	7.6	35.2	42.0	27.3	29.1
17	10.9	19.9	7.6	45.1	47.0	28.5	29.8
18	12.8	23.6	7.6	55.5	52.3	29.7	30.5
19	14.9	27.4	7.6	66.6	57.9	31.0	31.2
20	17.1	31.5	7.6	78.3	63.9	32.4	32.0
21	19.4	35.7	7.6	90.6	70.1	33.9	32.9
22	21.9	40.2	7.6	103.5	76.7	35.4	33.7
23	24.4	44.9	7.6	116.9	83.5	37.0	34.6
24	27.0	49.7	7.6	131.0	90.6	38.6	35.6
25	29.8	54.8	7.6	145.7	98.1	40.4	36.6
26	32.7	60.1	7.6	160.9	105.9	42.2	37.6
27	35.6	65.6	7.6	176.8	113.9	44.0	38.7
TREE GRADE 2 2-1/2 LOGS							
13	4.6	11.5	7.6	13.6	38.4	32.2	29.7
14	6.3	14.3	7.6	22.2	42.6	33.3	31.0
15	8.2	17.3	7.6	31.4	47.0	34.5	32.4
16	10.3	20.5	7.6	41.2	51.8	35.7	33.9
17	12.4	24.0	7.6	51.6	56.9	37.1	35.5
18	14.7	27.6	7.6	62.7	62.3	38.5	37.1
19	17.1	31.4	7.6	74.4	68.0	40.0	38.9
20	19.7	35.5	7.6	86.8	74.1	41.6	40.8
21	22.3	39.8	7.6	99.7	80.4	43.3	42.8
22	25.2	44.2	7.6	113.3	87.0	45.1	44.9

CONTINUED

Table 18.—Continued: SUGAR MAPLE

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
23	28.1	48.9	7.6	127.6	94.0	46.9	47.0
24	31.2	53.8	7.6	142.5	101.2	48.8	49.3
25	34.4	58.9	7.6	158.0	108.8	50.8	51.7
26	37.7	64.2	7.6	174.1	116.7	52.9	54.1
27	41.2	69.7	7.6	190.9	124.8	55.1	56.7
TREE GRADE 2 3 LOGS							
18	16.6	31.6	7.6	69.9	72.3	47.3	43.8
19	19.3	35.5	7.6	82.2	78.1	49.0	46.6
20	22.2	39.5	7.6	95.2	84.2	50.8	49.6
21	25.3	43.8	7.6	108.9	90.6	52.7	52.7
22	28.5	48.3	7.6	123.2	97.4	54.7	56.0
23	31.8	52.9	7.6	138.3	104.4	56.8	59.4
24	35.3	57.8	7.6	153.9	111.8	59.0	63.0
25	38.9	62.9	7.6	170.3	119.5	61.3	66.8
26	42.7	68.2	7.6	187.3	127.5	63.6	70.7
27	46.7	73.7	7.6	205.0	135.8	66.1	74.7
28	50.8	79.4	7.6	223.3	144.4	68.6	78.9
TREE GRADE 3 1 LOG							
10	0.5	0.0	1.6	0.0	11.2	0.9	20.2
11	.6	.0	1.9	.0	12.7	3.5	20.5
12	.6	.6	2.3	3.0	14.4	6.3	20.9
13	.7	1.8	2.7	7.8	16.2	9.3	21.3
14	.8	3.2	3.1	13.1	18.2	12.6	21.7
15	.8	4.7	3.6	18.7	20.3	16.1	22.2
16	.9	6.3	4.1	24.7	22.6	19.9	22.7
17	1.0	8.0	4.6	31.1	25.0	23.9	23.2
18	1.1	9.8	5.2	37.9	27.5	28.2	23.7
19	1.1	11.7	5.8	45.1	30.2	32.7	24.3
20	1.2	13.7	6.4	52.6	33.1	37.4	25.0
21	1.3	15.9	7.1	60.6	36.1	42.4	25.6
TREE GRADE 3 1-1/2 LOGS							
10	0.0	0.0	1.6	0.0	9.8	13.4	30.6
11	.0	.4	1.9	2.3	12.4	15.6	31.2
12	.3	1.5	2.3	6.7	15.3	17.9	31.9
13	.6	2.6	2.7	11.6	18.4	20.5	32.6
14	.9	3.9	3.1	16.8	21.8	23.3	33.4
15	1.2	5.3	3.6	22.4	25.4	26.2	34.2
16	1.5	6.7	4.1	28.4	29.3	29.4	35.1
17	1.9	8.3	4.6	34.8	33.5	32.8	36.0
18	2.3	9.9	5.2	41.6	37.8	36.4	37.1
19	2.7	11.7	5.8	48.8	42.5	40.2	38.1
20	3.1	13.5	6.4	56.4	47.3	44.2	39.2
21	3.6	15.5	7.1	64.3	52.5	48.4	40.4
22	4.0	17.5	7.8	72.7	57.8	52.8	41.7
23	4.5	19.6	8.5	81.4	63.5	57.4	43.0
24	5.1	21.8	9.2	90.5	69.3	62.3	44.3

CONTINUED

Table 18.—Continued: SUGAR MAPLE

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 3 2 LOGS							
10	0.0	0.5	1.6	1.9	8.4	25.9	41.0
11	.0	1.4	1.9	6.0	12.2	27.6	41.9
12	.0	2.4	2.3	10.4	16.2	29.6	42.8
13	.4	3.4	2.7	15.3	20.7	31.6	43.9
14	.9	4.6	3.1	20.5	25.5	33.9	45.0
15	1.5	5.8	3.6	26.2	30.6	36.3	46.2
16	2.1	7.2	4.1	32.2	36.1	38.9	47.5
17	2.8	8.6	4.6	38.6	41.9	41.7	48.9
18	3.5	10.1	5.2	45.4	48.1	44.6	50.4
19	4.2	11.7	5.8	52.5	54.7	47.7	51.9
20	5.0	13.3	6.4	60.1	61.6	51.0	53.5
21	5.8	15.1	7.1	68.1	68.9	54.4	55.2
22	6.7	16.9	7.8	76.4	76.5	58.0	57.0
23	7.6	18.8	8.5	85.1	84.5	61.7	58.9
24	8.5	20.9	9.2	94.2	92.8	65.7	60.9
25	9.5	23.0	10.0	103.7	101.5	69.8	62.9
26	10.5	25.1	10.8	113.6	110.5	74.0	65.1
27	11.6	27.4	11.7	123.9	119.9	78.5	67.3
28	12.7	29.8	12.6	134.6	129.7	83.1	69.6
TREE GRADE 3 2-1/2 LOGS							
15	1.9	6.4	3.6	29.9	35.7	46.4	58.2
16	2.8	7.6	4.1	35.9	42.8	48.4	59.9
17	3.7	8.8	4.6	42.3	50.4	50.6	61.7
18	4.7	10.2	5.2	49.1	58.4	52.8	63.7
19	5.8	11.6	5.8	56.3	66.9	55.2	65.7
20	6.9	13.1	6.4	63.8	75.9	57.7	67.8
21	8.1	14.7	7.1	71.8	85.3	60.4	70.1
22	9.3	16.3	7.8	80.1	95.1	63.1	72.4
23	10.6	18.1	8.5	88.9	105.5	66.1	74.9
24	12.0	19.9	9.2	98.0	116.3	69.1	77.5
25	13.4	21.8	10.0	107.5	127.5	72.3	80.1
26	14.8	23.7	10.8	117.4	139.2	75.5	82.9
27	16.3	25.8	11.7	127.7	151.3	79.0	85.8
28	17.9	27.9	12.6	138.3	164.0	82.5	88.8

Table 19.—Lumber grade volume for BLACK CHERRY

[In board feet]

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 1 1-1/2 LOGS						
16	50.5	26.7	26.7	24.4	12.1	14.0
17	53.5	33.6	38.2	28.2	13.5	11.9
18	56.7	40.8	50.4	32.2	15.0	9.8
19	60.1	48.5	63.2	36.5	16.5	7.5
20	63.6	56.6	76.8	40.9	18.2	5.1
TREE GRADE 1 2 LOGS						
16	46.0	32.1	34.9	37.0	22.7	11.8
17	52.1	39.0	46.0	41.4	24.3	11.2
18	58.5	46.2	57.7	46.1	26.0	10.5
19	65.3	53.8	70.1	51.1	27.8	9.7
20	72.4	61.9	83.2	56.3	29.7	8.9
21	79.9	70.3	97.0	61.8	31.7	8.1
22	87.8	79.2	111.4	67.6	33.8	7.2
23	96.1	88.5	126.5	73.6	36.0	6.3
24	104.7	98.2	142.3	79.9	38.3	5.3
25	113.7	108.3	158.7	86.5	40.7	4.3
TREE GRADE 1 2-1/2 LOGS						
16	41.6	37.6	43.0	49.6	33.3	9.7
17	50.6	44.3	53.7	54.6	35.1	10.4
18	60.3	51.5	65.0	60.0	37.1	11.1
19	70.5	59.1	77.0	65.7	39.1	11.9
20	81.2	67.1	89.6	71.7	41.3	12.7
21	92.5	75.5	102.9	78.0	43.6	13.5
22	104.3	84.4	116.8	84.6	46.0	14.4
23	116.7	93.6	131.4	91.6	48.5	15.3
24	129.7	103.2	146.6	98.8	51.1	16.3
25	143.2	113.3	162.5	106.3	53.8	17.3
TREE GRADE 1 3 LOGS						
16	37.1	43.0	51.2	62.1	43.9	7.6
17	49.2	49.7	61.5	67.8	46.0	9.6
18	62.1	56.9	72.4	73.9	48.1	11.8
19	75.7	64.4	83.9	80.3	50.4	14.0
20	90.0	72.4	96.1	87.1	52.9	16.4
21	105.0	80.7	108.9	94.2	55.4	19.0
22	120.8	89.5	122.3	101.7	58.1	21.6
23	137.4	98.7	136.3	109.5	60.9	24.4
24	154.6	108.3	150.9	117.6	63.8	27.3
25	172.6	118.2	166.2	126.1	66.9	30.3
TREE GRADE 2 1-1/2 LOGS						
13	5.0	16.6	21.3	29.4	18.8	1.7
14	6.1	20.3	27.1	32.4	18.8	2.2
15	7.3	24.3	33.3	35.5	18.8	2.8
16	8.6	28.6	40.0	38.9	18.8	3.4
17	9.9	33.1	47.1	42.4	18.8	4.1
18	11.4	37.9	54.6	46.2	18.8	4.8
19	12.9	43.0	62.6	50.2	18.8	5.5
20	14.5	48.4	71.0	54.5	18.8	6.3

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Table 19.—Continued: BLACK CHERRY

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
21	16.2	54.1	79.8	58.9	18.8	7.1
22	18.0	60.0	89.0	63.6	18.8	7.9
23	19.8	66.2	98.7	68.5	18.8	8.8
24	21.7	72.7	108.8	73.6	18.8	9.8
TREE GRADE 2 2 LOGS						
13	10.7	20.5	16.1	35.0	28.8	4.9
14	12.6	23.9	23.9	38.8	28.8	5.3
15	14.7	27.5	32.3	42.9	28.8	5.8
16	17.0	31.4	41.3	47.3	28.8	6.3
17	19.3	35.5	50.8	51.9	28.8	6.8
18	21.9	39.8	60.9	56.8	28.8	7.3
19	24.5	44.4	71.6	62.0	28.8	7.9
20	27.3	49.3	82.9	67.5	28.8	8.5
21	30.3	54.4	94.7	73.2	28.8	9.1
22	33.4	59.7	107.2	79.3	28.8	9.8
23	36.6	65.3	120.2	85.6	28.8	10.5
24	40.0	71.2	133.7	92.2	28.8	11.2
TREE GRADE 2 2-1/2 LOGS						
13	16.4	24.5	11.0	40.7	38.8	8.2
14	19.2	27.5	20.8	45.3	38.8	8.5
15	22.2	30.7	31.3	50.3	38.8	8.8
16	25.3	34.2	42.6	55.7	38.8	9.1
17	28.7	37.8	54.5	61.4	38.8	9.5
18	32.3	41.7	67.2	67.4	38.8	9.9
19	36.1	45.8	80.6	73.8	38.8	10.3
20	40.2	50.2	94.8	80.5	38.8	10.7
21	44.4	54.7	109.7	87.6	38.8	11.2
22	48.8	59.5	125.3	95.0	38.8	11.6
23	53.4	64.5	141.6	102.7	38.8	12.1
24	58.2	69.7	158.6	110.8	38.8	12.6
TREE GRADE 2 3 LOGS						
13	22.1	28.5	5.8	46.3	48.8	11.4
14	25.7	31.1	17.6	51.8	48.8	11.6
15	29.6	34.0	30.3	57.7	48.8	11.8
16	33.7	37.0	43.8	64.1	48.8	12.0
17	38.1	40.2	58.2	70.8	48.8	12.2
18	42.8	43.6	73.5	78.0	48.8	12.4
19	47.8	47.2	89.7	85.5	48.8	12.7
20	53.0	51.0	106.7	93.5	48.8	12.9
21	58.5	55.0	124.6	101.9	48.8	13.2
22	64.2	59.2	143.4	110.7	48.8	13.5
23	70.2	63.6	163.0	119.9	48.8	13.8
24	76.5	68.2	183.5	129.5	48.8	14.1
TREE GRADE 3 1 LOG						
10	3.7	8.8	5.1	16.4	8.8	3.6
11	3.9	9.2	10.0	18.0	9.3	3.6
12	4.2	9.7	15.2	19.7	9.8	3.6
13	4.6	10.2	21.0	21.5	10.3	3.6
14	4.9	10.7	27.2	23.5	10.9	3.6
15	5.3	11.3	33.9	25.6	11.5	3.6
16	5.7	11.9	41.0	27.9	12.2	3.6
17	6.2	12.5	48.6	30.3	12.9	3.6
18	6.6	13.2	56.6	32.9	13.6	3.6
19	7.1	14.0	65.2	35.6	14.4	3.6
20	7.6	14.7	74.1	38.5	15.3	3.6

CONTINUED

Table 19.—Continued: BLACK CHERRY

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 3 1-1/2 LOGS						
10	0.0	4.4	2.7	20.8	19.2	6.7
11	1.0	5.9	8.3	23.1	19.9	6.7
12	2.1	7.7	14.5	25.6	20.7	6.7
13	3.3	9.6	21.2	28.3	21.6	6.7
14	4.6	11.6	28.5	31.2	22.5	6.7
15	6.0	13.8	36.3	34.4	23.5	6.7
16	7.5	16.1	44.6	37.7	24.6	6.7
17	9.1	18.6	53.5	41.3	25.8	6.7
18	10.7	21.3	62.9	45.1	27.0	6.7
19	12.5	24.0	72.8	49.2	28.3	6.7
20	14.4	27.0	83.3	53.4	29.7	6.7
TREE GRADE 3 2 LOGS						
10	0.0	0.0	0.2	25.1	29.5	9.9
11	.0	2.6	6.7	28.1	30.5	9.9
12	.0	5.7	13.8	31.4	31.6	9.9
13	2.1	8.9	21.5	35.0	32.8	9.9
14	4.3	12.5	29.8	38.9	34.1	9.9
15	6.7	16.3	38.7	43.1	35.6	9.9
16	9.2	20.4	48.2	47.6	37.1	9.9
17	12.0	24.7	58.3	52.3	38.7	9.9
18	14.8	29.3	69.1	57.4	40.4	9.9
19	17.9	34.1	80.5	62.7	42.2	9.9
20	21.1	39.2	92.5	68.4	44.1	9.9
TREE GRADE 3 2-1/2 LOGS						
10	0.0	0.0	0.0	29.4	39.8	13.0
11	.0	.0	5.1	33.2	41.1	13.0
12	.0	3.6	13.0	37.3	42.5	13.0
13	.8	8.3	21.7	41.8	44.1	13.0
14	4.0	13.4	31.0	46.6	45.8	13.0
15	7.4	18.8	41.1	51.9	47.6	13.0
16	11.0	24.6	51.8	57.4	49.5	13.0
17	14.9	30.7	63.2	63.4	51.6	13.0
18	19.0	37.3	75.3	69.6	53.7	13.0
19	23.3	44.2	88.1	76.3	56.0	13.0
20	27.8	51.5	101.6	83.3	58.4	13.0
TREE GRADE 3 3 LOGS						
13	0.0	7.7	21.9	48.6	55.4	16.1
14	3.7	14.2	32.3	54.4	57.4	16.1
15	8.0	21.3	43.5	60.6	59.6	16.1
16	12.8	28.8	55.4	67.3	61.9	16.1
17	17.8	36.8	68.1	74.4	64.4	16.1
18	23.1	45.3	81.6	81.9	67.1	16.1
19	28.7	54.3	95.8	89.9	69.9	16.1
20	34.6	63.8	110.8	98.2	72.8	16.1

Table 20.—Lumber grade volume for PAPER BIRCH

[In board feet]

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 1 1-1/2 LOGS						
16	22.5	27.9	31.8	34.3	18.9	8.8
17	25.2	30.5	35.4	37.4	19.8	11.3
18	28.0	33.3	39.3	40.7	20.7	13.9
19	30.9	36.3	43.4	44.2	21.7	16.8
20	34.0	39.5	47.7	47.8	22.7	19.7
21	37.3	42.8	52.2	51.7	23.8	22.9
22	40.7	46.2	57.0	55.7	24.9	26.1
23	44.3	49.8	62.0	59.9	26.1	29.6
TREE GRADE 1 2 LOGS						
16	22.5	29.2	29.4	36.8	27.3	14.9
17	25.2	32.7	35.3	40.6	29.2	17.8
18	28.0	36.4	41.7	44.6	31.2	20.8
19	30.9	40.3	48.3	48.8	33.4	24.0
20	34.0	44.4	55.3	53.3	35.6	27.3
21	37.3	48.8	62.7	57.9	38.0	30.8
22	40.7	53.3	70.5	62.9	40.5	34.5
23	44.3	58.0	78.6	68.0	43.2	38.4
TREE GRADE 1 2-1/2 LOGS						
16	22.5	30.6	27.0	39.3	35.7	21.1
17	25.2	34.9	35.3	43.8	38.6	24.2
18	28.0	39.5	44.0	48.5	41.8	27.6
19	30.9	44.3	53.3	53.4	45.1	31.1
20	34.0	49.4	63.0	58.7	48.6	34.9
21	37.3	54.7	73.2	64.2	52.3	38.8
22	40.7	60.4	84.0	70.0	56.1	42.9
23	44.3	66.2	95.2	76.1	60.2	47.2
TREE GRADE 2 1-1/2 LOGS						
13	5.1	12.6	13.5	19.2	22.0	6.4
14	5.5	15.4	16.8	21.5	22.6	8.6
15	6.0	18.4	20.3	23.9	23.2	11.0
16	6.6	21.6	24.0	26.6	23.9	13.5
17	7.1	25.0	28.0	29.4	24.6	16.2
18	7.7	28.6	32.2	32.3	25.4	19.1
19	8.4	32.4	36.7	35.5	26.2	22.1
20	9.0	36.4	41.4	38.8	27.0	25.3
21	9.7	40.7	46.3	42.3	27.9	28.7
TREE GRADE 2 2 LOGS						
13	4.1	12.6	14.6	26.9	28.7	14.9
14	5.4	15.4	18.5	29.1	29.8	16.2
15	6.8	18.4	22.7	31.5	31.0	17.6
16	8.4	21.6	27.3	34.0	32.3	19.1
17	10.0	25.0	32.1	36.7	33.6	20.7
18	11.7	28.6	37.1	39.6	35.0	22.4
19	13.5	32.4	42.5	42.6	36.5	24.2
20	15.5	36.4	48.2	45.8	38.1	26.1
21	17.5	40.7	54.2	49.1	39.8	28.1

CONTINUED

Table 20.—Continued: PAPER BIRCH

Dbh (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 2 2-1/2 LOGS						
13	3.1	12.6	15.6	34.6	35.4	23.3
14	5.3	15.4	20.2	36.7	37.0	23.7
15	7.6	18.4	25.2	39.0	38.8	24.2
16	10.2	21.6	30.5	41.4	40.6	24.7
17	12.9	25.0	36.1	44.0	42.6	25.2
18	15.7	28.6	42.1	46.8	44.7	25.7
19	18.7	32.4	48.4	49.7	46.9	26.3
20	21.9	36.4	55.0	52.8	49.2	26.9
21	25.2	40.7	62.0	56.0	51.7	27.5
TREE GRADE 3 1 LOG						
10	0.2	2.2	2.8	14.2	10.7	7.5
11	.5	2.5	5.1	15.1	12.4	8.3
12	.8	2.7	7.7	16.1	14.3	9.1
13	1.2	3.0	10.6	17.1	16.3	10.1
14	1.5	3.3	13.7	18.3	18.5	11.1
15	1.9	3.7	16.9	19.5	20.9	12.2
16	2.4	4.0	20.5	20.8	23.4	13.3
17	2.8	4.4	24.2	22.2	26.0	14.6
18	3.3	4.8	28.2	23.7	28.9	15.9
19	3.8	5.2	32.4	25.3	31.9	17.3
20	4.4	5.6	36.8	27.0	35.0	18.8
TREE GRADE 3 1-1/2 LOGS						
10	0.0	4.3	3.4	13.1	15.1	14.0
11	.2	4.6	6.3	15.4	17.0	14.8
12	.7	5.0	9.4	18.0	19.0	15.6
13	1.3	5.5	12.8	20.8	21.3	16.5
14	1.9	5.9	16.4	23.8	23.7	17.5
15	2.6	6.4	20.3	27.0	26.2	18.5
16	3.3	7.0	24.5	30.4	29.0	19.6
17	4.1	7.5	29.0	34.1	31.9	20.8
18	4.9	8.1	33.7	38.0	35.0	22.0
19	5.8	8.8	38.7	42.1	38.3	23.3
20	6.7	9.4	44.0	46.5	41.8	24.7
TREE GRADE 3 2 LOGS						
10	0.0	6.3	4.1	11.9	19.5	20.6
11	.0	6.8	7.4	15.7	21.6	21.3
12	.6	7.3	11.0	19.9	23.8	22.1
13	1.4	7.9	14.9	24.4	26.2	22.9
14	2.3	8.5	19.2	29.2	28.8	23.8
15	3.3	9.2	23.7	34.5	31.6	24.8
16	4.3	9.9	28.6	40.0	34.6	25.9
17	5.4	10.7	33.8	46.0	37.8	27.0
18	6.5	11.5	39.3	52.3	41.2	28.2
19	7.8	12.3	45.1	59.0	44.7	29.4
20	9.1	13.2	51.2	66.0	48.5	30.7
TREE GRADE 3 2-1/2 LOGS						
10	0.0	8.4	4.8	10.8	23.9	27.2
11	.0	9.0	8.5	16.0	26.1	27.8
12	.5	9.6	12.6	21.7	28.5	28.6
13	1.6	10.4	17.1	28.0	31.1	29.4
14	2.7	11.1	21.9	34.7	33.9	30.2
15	3.9	12.0	27.1	41.9	37.0	31.1
16	5.3	12.9	32.7	49.6	40.2	32.1
17	6.7	13.8	38.6	57.9	43.7	33.2
18	8.2	14.8	44.8	66.6	47.3	34.3
19	9.7	15.9	51.4	75.8	51.2	35.5
20	11.4	17.0	58.4	85.5	55.3	36.7

Table 21.—Lumber grade volume for WHITE OAK

[In board feet]

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
TREE GRADE 1 1-1/2 LOGS								
16	9.1	9.9	0.0	35.3	18.0	5.3	19.5	22.6
17	13.9	13.6	.0	39.6	23.5	4.9	22.3	23.1
18	18.9	17.5	1.2	44.1	29.4	4.5	25.2	23.6
19	24.3	21.7	2.6	49.0	35.6	4.0	28.2	24.2
20	30.0	26.0	4.1	54.0	42.1	3.5	31.5	24.8
21	35.9	30.6	5.6	59.4	49.0	3.0	34.9	25.4
22	42.2	35.4	7.3	65.0	56.2	2.5	38.4	26.1
23	48.7	40.4	9.0	70.8	63.7	1.9	42.1	26.8
24	55.6	45.7	10.8	77.0	71.6	1.3	46.0	27.5
25	62.7	51.2	12.6	83.3	79.8	.7	50.1	28.3
26	70.1	56.9	14.6	90.0	88.3	.0	54.3	29.1
TREE GRADE 1 2 LOGS								
16	9.1	9.9	1.2	28.0	34.2	7.4	31.6	26.2
17	13.9	13.6	2.4	35.9	40.4	8.1	34.0	26.9
18	18.9	17.5	3.6	44.3	47.1	8.9	36.5	27.7
19	24.3	21.7	4.8	53.2	54.1	9.7	39.2	28.5
20	30.0	26.0	6.2	62.6	61.5	10.5	42.1	29.3
21	35.9	30.6	7.6	72.4	69.3	11.4	45.1	30.2
22	42.2	35.4	9.1	82.7	77.5	12.4	48.2	31.1
23	48.7	40.4	10.6	93.6	86.0	13.4	51.5	32.1
24	55.6	45.7	12.2	104.8	95.0	14.4	54.9	33.1
25	62.7	51.2	13.9	116.6	104.3	15.4	58.5	34.1
26	70.1	56.9	15.7	128.9	114.0	16.5	62.2	35.2
TREE GRADE 1 2-1/2 LOGS								
16	9.1	9.9	3.9	20.6	50.3	9.5	43.7	29.9
17	13.9	13.6	4.9	32.2	57.3	11.3	45.7	30.8
18	18.9	17.5	6.0	44.5	64.8	13.3	47.9	31.7
19	24.3	21.7	7.1	57.4	72.7	15.4	50.3	32.7
20	30.0	26.0	8.3	71.1	81.0	17.6	52.7	33.8
21	35.9	30.6	9.6	85.4	89.7	19.9	55.3	34.9
22	42.2	35.4	10.9	100.5	98.8	22.3	58.0	36.1
23	48.7	40.4	12.2	116.3	108.4	24.8	60.8	37.3
24	55.6	45.7	13.7	132.7	118.4	27.4	63.7	38.6
25	62.7	51.2	15.2	149.9	128.8	30.2	66.8	39.9
26	70.1	56.9	16.7	167.8	139.6	33.0	70.0	41.3
TREE GRADE 1 3 LOGS								
16	9.1	9.9	6.6	13.3	66.5	11.6	55.8	33.5
17	13.9	13.6	7.5	28.5	74.3	14.6	57.5	34.6
18	18.9	17.5	8.4	44.6	82.5	17.7	59.3	35.7
19	24.3	21.7	9.4	61.7	91.2	21.1	61.3	37.0
20	30.0	26.0	10.4	79.6	100.4	24.6	63.3	38.3
21	35.9	30.6	11.5	98.5	110.0	28.3	65.5	39.6
22	42.2	35.4	12.7	118.3	120.1	32.2	67.7	41.0
23	48.7	40.4	13.9	139.0	130.7	36.3	70.1	42.5
24	55.6	45.7	15.1	160.6	141.8	40.5	72.6	44.1
25	62.7	51.2	16.4	183.2	153.3	44.9	75.2	45.7
26	70.1	56.9	17.8	206.6	165.3	49.5	77.8	47.4
27	77.8	62.8	19.2	231.0	177.8	54.3	80.6	49.2
28	85.8	69.0	20.7	256.4	190.7	59.3	83.5	51.0

CONTINUED

Table 21.—Continued: WHITE OAK

TREE GRADE 1
3-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
16	9.1	9.9	9.3	6.0	82.7	13.7	67.8	37.1
17	13.9	13.6	10.0	24.8	91.2	17.8	69.2	38.4
18	18.9	17.5	10.8	44.8	100.2	22.1	70.7	39.8
19	24.3	21.7	11.7	65.9	109.7	26.8	72.3	41.2
20	30.0	26.0	12.6	88.1	119.8	31.6	74.0	42.8
21	35.9	30.6	13.5	111.5	130.4	36.7	75.7	44.3
22	42.2	35.4	14.5	136.0	141.5	42.1	77.5	46.0
23	48.7	40.4	15.5	161.7	153.1	47.7	79.4	47.8
24	55.6	45.7	16.6	188.5	165.2	53.6	81.4	49.6
25	62.7	51.2	17.7	216.5	177.8	59.7	83.5	51.5
26	70.1	56.9	18.9	245.5	191.0	66.0	85.7	53.5
27	77.8	62.8	20.1	275.8	204.6	72.7	87.9	55.6
28	85.8	69.0	21.3	307.1	218.8	79.5	90.3	57.7
29	94.1	75.3	22.6	339.6	233.5	86.6	92.7	59.9
30	102.6	81.9	24.0	373.3	248.7	94.0	95.2	62.2

TREE GRADE 1
4 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
16	9.1	9.9	12.0	0.0	98.8	15.7	79.9	40.8
17	13.9	13.6	12.6	21.1	108.1	21.0	81.0	42.3
18	18.9	17.5	13.3	44.9	117.9	26.6	82.1	43.8
19	24.3	21.7	14.0	70.1	128.3	32.4	83.3	45.5
20	30.0	26.0	14.7	96.6	139.2	38.6	84.6	47.2
21	35.9	30.6	15.5	124.5	150.7	45.2	85.9	49.1
22	42.2	35.4	16.3	153.8	162.8	52.0	87.3	51.0
23	48.7	40.4	17.1	184.4	175.4	59.2	88.8	53.0
24	55.6	45.7	18.0	216.4	188.6	66.6	90.3	55.1
25	62.7	51.2	19.0	249.7	202.3	74.4	91.9	57.3
26	70.1	56.9	19.9	284.4	216.6	82.5	93.5	59.6
27	77.8	62.8	20.9	320.5	231.5	91.0	95.2	62.0
28	85.8	69.0	22.0	357.9	246.9	99.7	97.0	64.4
29	94.1	75.3	23.1	396.7	262.9	108.8	98.9	67.0
30	102.6	81.9	24.2	436.8	279.5	118.2	100.8	69.6

TREE GRADE 2
1 LOG

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
13	1.6	3.8	3.9	0.0	3.8	0.0	16.6	18.4
14	2.7	5.2	3.9	.0	7.9	.0	17.4	18.4
15	4.0	6.8	3.9	4.5	12.2	.0	18.3	18.4
16	5.4	8.5	3.9	14.9	16.9	.0	19.2	18.4
17	6.8	10.3	3.9	25.9	21.9	.0	20.2	18.4
18	8.4	12.2	3.9	37.6	27.1	.0	21.3	18.4
19	10.0	14.2	3.9	50.0	32.7	2.2	22.4	18.4
20	11.7	16.3	3.9	63.0	38.5	4.7	23.6	18.4

TREE GRADE 2
1-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
13	1.6	3.8	3.9	0.0	10.0	0.0	21.1	24.8
14	2.7	5.2	3.9	.0	15.4	1.7	22.6	24.8
15	4.0	6.8	3.9	9.8	21.3	3.5	24.2	24.8
16	5.4	8.5	3.9	20.5	27.5	5.5	25.9	24.8
17	6.8	10.3	3.9	31.8	34.2	7.6	27.8	24.8
18	8.4	12.2	3.9	43.9	41.2	9.8	29.7	24.8
19	10.0	14.2	3.9	56.6	48.7	12.1	31.8	24.8
20	11.7	16.3	3.9	70.0	56.6	14.6	33.9	24.8
21	13.6	18.5	3.9	84.2	64.8	17.2	36.2	24.8
22	15.4	20.9	3.9	99.0	73.5	19.9	38.6	24.8
23	17.4	23.3	3.9	114.5	82.6	22.8	41.1	24.8

CONTINUED

Table 21.—Continued: WHITE OAK

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
TREE GRADE 2 2 LOGS								
13	1.6	3.8	3.9	0.0	16.1	9.8	25.6	31.3
14	2.7	5.2	3.9	4.8	23.0	11.5	27.8	31.3
15	4.0	6.8	3.9	15.0	30.3	13.3	30.1	31.3
16	5.4	8.5	3.9	26.0	38.1	15.3	32.6	31.3
17	6.8	10.3	3.9	37.7	46.5	17.4	35.3	31.3
18	8.4	12.2	3.9	50.1	55.4	19.7	38.1	31.3
19	10.0	14.2	3.9	63.3	64.7	22.0	41.1	31.3
20	11.7	16.3	3.9	77.1	74.6	24.5	44.3	31.3
21	13.6	18.5	3.9	91.6	85.0	27.1	47.6	31.3
22	15.4	20.9	3.9	106.9	95.9	29.8	51.0	31.3
23	17.4	23.3	3.9	122.8	107.3	32.7	54.7	31.3
24	19.5	25.9	3.9	139.5	119.2	35.7	58.5	31.3
25	21.7	28.5	3.9	156.8	131.6	38.8	62.4	31.3
TREE GRADE 2 2-1/2 LOGS								
13	1.6	3.8	3.9	0.0	22.3	19.6	30.1	37.7
14	2.7	5.2	3.9	9.7	30.5	21.3	33.0	37.7
15	4.0	6.8	3.9	20.3	39.3	23.2	36.0	37.7
16	5.4	8.5	3.9	31.6	48.8	25.2	39.3	37.7
17	6.8	10.3	3.9	43.6	58.8	27.3	42.8	37.7
18	8.4	12.2	3.9	56.4	69.5	29.5	46.5	37.7
19	10.0	14.2	3.9	69.9	80.8	31.9	50.5	37.7
20	11.7	16.3	3.9	84.1	92.6	34.4	54.6	37.7
21	13.6	18.5	3.9	99.1	105.1	37.0	58.9	37.7
22	15.4	20.9	3.9	114.8	118.2	39.8	63.5	37.7
23	17.4	23.3	3.9	131.2	131.9	42.7	68.3	37.7
24	19.5	25.9	3.9	148.3	146.2	45.7	73.2	37.7
25	21.7	28.5	3.9	166.2	161.2	48.8	78.4	37.7
TREE GRADE 2 3 LOGS								
13	1.6	3.8	3.9	4.6	28.4	29.5	34.6	44.1
14	2.7	5.2	3.9	14.7	38.0	31.2	38.2	44.1
15	4.0	6.8	3.9	25.6	48.4	33.1	42.0	44.1
16	5.4	8.5	3.9	37.2	59.4	35.1	46.0	44.1
17	6.8	10.3	3.9	49.6	71.1	37.2	50.4	44.1
18	8.4	12.2	3.9	62.7	83.6	39.4	55.0	44.1
19	10.0	14.2	3.9	76.6	96.8	41.8	59.8	44.1
20	11.7	16.3	3.9	91.2	110.7	44.3	64.9	44.1
21	13.6	18.5	3.9	106.5	125.3	47.0	70.3	44.1
22	15.4	20.9	3.9	122.7	140.6	49.7	75.9	44.1
23	17.4	23.3	3.9	139.5	156.6	52.6	81.9	44.1
24	19.5	25.9	3.9	157.1	173.3	55.6	88.0	44.1
25	21.7	28.5	3.9	175.5	190.8	58.8	94.4	44.1
26	23.9	31.3	3.9	194.6	208.9	62.1	101.1	44.1
TREE GRADE 2 3-1/2 LOGS								
13	1.6	3.8	3.9	9.3	34.6	39.3	39.1	50.6
14	2.7	5.2	3.9	19.7	45.6	41.0	43.4	50.6
15	4.0	6.8	3.9	30.8	57.4	42.9	47.9	50.6
16	5.4	8.5	3.9	42.8	70.0	44.9	52.8	50.6
17	6.8	10.3	3.9	55.5	83.5	47.0	57.9	50.6
18	8.4	12.2	3.9	68.9	97.7	49.3	63.4	50.6
19	10.0	14.2	3.9	83.2	112.8	51.7	69.2	50.6
20	11.7	16.3	3.9	98.2	128.7	54.2	75.3	50.6
21	13.6	18.5	3.9	114.0	145.4	56.9	81.7	50.6
22	15.4	20.9	3.9	130.6	162.9	59.7	88.4	50.6
23	17.4	23.3	3.9	147.9	181.2	62.6	95.4	50.6
24	19.5	25.9	3.9	166.0	200.4	65.6	102.8	50.6

CONTINUED

Table 21.—Continued: WHITE OAK

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
25	21.7	28.5	3.9	184.8	220.4	68.8	110.4	50.6
26	23.9	31.3	3.9	204.5	241.1	72.1	118.4	50.6
27	26.3	34.2	3.9	224.9	262.7	75.5	126.7	50.6
28	28.7	37.2	3.9	246.1	285.1	79.1	135.3	50.6
29	31.2	40.3	3.9	268.0	308.4	82.8	144.2	50.6
TREE GRADE 3 1 LOG								
10	0.0	0.0	0.3	12.9	5.9	0.0	3.4	12.4
11	.0	.0	.3	15.4	8.9	.0	5.4	13.0
12	.0	.6	.3	18.0	12.3	.0	7.6	13.7
13	.6	1.2	.3	20.9	15.9	1.0	9.9	14.4
14	1.2	1.9	.3	24.0	19.8	2.4	12.4	15.2
15	1.9	2.6	.3	27.4	24.0	3.9	15.2	16.0
16	2.5	3.3	.3	31.0	28.5	5.6	18.1	17.0
17	3.3	4.1	.3	34.8	33.3	7.4	21.1	17.9
18	4.1	5.0	.3	38.8	38.4	9.2	24.4	18.9
19	4.9	5.9	.3	43.1	43.7	11.2	27.9	20.0
20	5.8	6.8	.3	47.6	49.4	13.3	31.5	21.1
21	6.7	7.8	.3	52.4	55.3	15.5	35.4	22.3
22	7.7	8.8	.3	57.4	61.6	17.8	39.4	23.6
TREE GRADE 3 1-1/2 LOGS								
10	0.0	0.0	0.8	0.0	5.4	0.2	10.9	25.7
11	.0	.0	.8	3.0	9.6	1.7	13.0	26.2
12	.0	.6	.8	7.0	14.2	3.4	15.2	26.8
13	.6	1.2	.8	11.3	19.3	5.3	17.6	27.4
14	1.2	1.9	.8	16.0	24.7	7.2	20.2	28.1
15	1.9	2.6	.8	21.1	30.6	9.4	23.1	28.8
16	2.5	3.3	.8	26.5	36.8	11.6	26.1	29.5
17	3.3	4.1	.8	32.2	43.5	14.0	29.3	30.4
18	4.1	5.0	.8	38.3	50.6	16.6	32.7	31.2
19	4.9	5.9	.8	44.8	58.0	19.3	36.3	32.1
20	5.8	6.8	.8	51.6	65.9	22.2	40.0	33.1
21	6.7	7.8	.8	58.7	74.2	25.1	44.0	34.1
22	7.7	8.8	.8	66.2	82.8	28.3	48.2	35.2
23	8.7	9.9	.8	74.1	91.9	31.6	52.6	36.3
24	9.7	11.1	.8	82.3	101.4	35.0	57.1	37.5
TREE GRADE 3 2 LOGS								
10	0.0	0.0	1.3	0.0	4.8	3.1	18.4	38.9
11	.0	.0	1.3	.0	10.3	5.1	20.5	39.4
12	.0	.6	1.3	.0	16.2	7.2	22.8	39.8
13	.6	1.2	1.3	1.8	22.7	9.6	25.3	40.3
14	1.2	1.9	1.3	8.0	29.7	12.1	28.0	40.9
15	1.9	2.6	1.3	14.8	37.2	14.8	31.0	41.5
16	2.5	3.3	1.3	22.0	45.2	17.6	34.1	42.1
17	3.3	4.1	1.3	29.7	53.7	20.7	37.4	42.8
18	4.1	5.0	1.3	37.9	62.8	24.0	40.9	43.5
19	4.9	5.9	1.3	46.5	72.3	27.4	44.6	44.3
20	5.8	6.8	1.3	55.6	82.4	31.0	48.5	45.1
21	6.7	7.8	1.3	65.1	93.0	34.8	52.7	45.9
22	7.7	8.8	1.3	75.1	104.1	38.8	57.0	46.8
23	8.7	9.9	1.3	85.6	115.8	43.0	61.5	47.7
24	9.7	11.1	1.3	96.5	127.9	47.4	66.2	48.6
25	10.8	12.3	1.3	108.0	140.6	51.9	71.1	49.6
26	12.0	13.5	1.3	119.8	153.8	56.7	76.3	50.7

CONTINUED

Table 21.—Continued: WHITE OAK

Dbh (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
TREE GRADE 3 2-1/2 LOGS								
13	0.6	1.2	1.8	0.0	26.1	13.9	33.0	53.3
14	1.2	1.9	1.8	.0	34.6	16.9	35.8	53.7
15	1.9	2.6	1.8	8.5	43.7	20.2	38.9	54.2
16	2.5	3.3	1.8	17.5	53.5	23.7	42.1	54.7
17	3.3	4.1	1.8	27.1	63.9	27.4	45.5	55.2
18	4.1	5.0	1.8	37.4	74.9	31.3	49.1	55.8
19	4.9	5.9	1.8	48.1	86.6	35.5	53.0	56.4
20	5.8	6.8	1.8	59.5	98.9	39.9	57.0	57.0
21	6.7	7.8	1.8	71.5	111.8	44.5	61.3	57.7
22	7.7	8.8	1.8	84.0	125.4	49.4	65.8	58.4
23	8.7	9.9	1.8	97.1	139.6	54.4	70.4	59.1
24	9.7	11.1	1.8	110.8	154.4	59.7	75.3	59.8
25	10.8	12.3	1.8	125.1	169.8	65.2	80.4	60.6
26	12.0	13.5	1.8	140.0	185.9	71.0	85.7	61.4
TREE GRADE 3 3 LOGS								
14	1.2	1.9	2.3	0.0	39.5	21.7	43.6	66.6
15	1.9	2.6	2.3	2.2	50.3	25.6	46.8	66.9
16	2.5	3.3	2.3	13.0	61.8	29.7	50.1	67.3
17	3.3	4.1	2.3	24.6	74.1	34.1	53.6	67.7
18	4.1	5.0	2.3	36.9	87.1	38.7	57.4	68.1
19	4.9	5.9	2.3	49.8	100.9	43.6	61.3	68.5
20	5.8	6.8	2.3	63.5	115.4	48.8	65.5	69.0
21	6.7	7.8	2.3	77.8	130.7	54.2	69.9	69.4
22	7.7	8.8	2.3	92.9	146.7	59.9	74.5	69.9
23	8.7	9.9	2.3	108.6	163.4	65.8	79.4	70.5
24	9.7	11.1	2.3	125.1	180.9	72.1	84.4	71.0
25	10.8	12.3	2.3	142.2	199.1	78.6	89.7	71.6
26	12.0	13.5	2.3	160.1	218.1	85.3	95.1	72.2
TREE GRADE 3 3-1/2 LOGS								
16	2.5	3.3	2.8	8.6	70.1	35.7	58.1	79.9
17	3.3	4.1	2.8	22.1	84.3	40.7	61.7	80.1
18	4.1	5.0	2.8	36.4	99.3	46.1	65.6	80.4
19	4.9	5.9	2.8	51.5	115.2	51.7	69.7	80.6
20	5.8	6.8	2.8	67.4	131.9	57.6	74.0	80.9
21	6.7	7.8	2.8	84.2	149.5	63.9	78.6	81.2
22	7.7	8.8	2.8	101.7	167.9	70.4	83.3	81.5
23	8.7	9.9	2.8	120.1	187.2	77.3	88.3	81.9
24	9.7	11.1	2.8	139.3	207.4	84.4	93.5	82.2
25	10.8	12.3	2.8	159.4	228.4	91.9	98.9	82.6
26	12.0	13.5	2.8	180.2	250.3	99.6	104.6	82.9

Table 22.—Lumber grade volume for YELLOW-POPLAR

[In board feet]

Dbh (inches)	FAS	Selects	SAPS	No. 1C	No. 2A	No. 2B	No. 3C
TREE GRADE 1 2 LOGS							
16	0.0	0.0	8.5	53.3	92.8	26.0	0.9
17	.0	1.6	10.3	74.0	102.6	23.3	1.6
18	.6	3.3	12.2	96.1	113.0	20.4	2.2
19	1.7	5.2	14.2	119.4	124.0	17.3	3.0
20	2.8	7.1	16.4	143.9	135.5	14.1	3.7
21	4.0	9.2	18.6	169.7	147.7	10.7	4.5
22	5.2	11.3	20.9	196.8	160.4	7.2	5.4
23	6.5	13.6	23.4	225.1	173.7	3.5	6.3
24	7.8	16.0	26.0	254.7	187.7	.0	7.2
25	9.2	18.4	28.6	285.5	202.2	.0	8.2
26	10.7	21.0	31.4	317.6	217.3	.0	9.2
TREE GRADE 1 2-1/2 LOGS							
16	0.0	1.6	8.5	55.5	105.0	40.7	2.1
17	.0	3.4	10.3	76.2	114.6	40.6	2.6
18	1.1	5.2	12.2	98.0	124.7	40.6	3.0
19	2.2	7.2	14.2	121.2	135.5	40.5	3.5
20	3.4	9.3	16.4	145.6	146.8	40.4	4.0
21	4.6	11.5	18.6	171.2	158.8	40.3	4.6
22	5.9	13.7	20.9	198.1	171.3	40.3	5.1
23	7.3	16.1	23.4	226.2	184.4	40.2	5.7
24	8.7	18.6	26.0	255.6	198.0	40.1	6.4
25	10.2	21.2	28.6	286.3	212.3	40.0	7.0
26	11.7	23.9	31.4	318.2	227.1	39.9	7.7
TREE GRADE 1 3 LOGS							
16	0.0	3.4	8.5	57.8	117.1	55.3	3.3
17	.4	5.2	10.3	78.3	126.5	57.9	3.6
18	1.5	7.2	12.2	100.0	136.5	60.7	3.8
19	2.7	9.2	14.2	123.0	147.1	63.6	4.1
20	4.0	11.4	16.4	147.2	158.2	66.7	4.3
21	5.3	13.7	18.6	172.7	169.9	69.9	4.6
22	6.6	16.1	20.9	199.4	182.2	73.3	4.9
23	8.1	18.6	23.4	227.4	195.0	76.9	5.2
24	9.6	21.3	26.0	256.6	208.4	80.6	5.5
25	11.1	24.0	28.6	287.0	222.4	84.4	5.9
26	12.8	26.9	31.4	318.7	237.0	88.5	6.2
27	14.5	29.8	34.3	351.7	252.1	92.6	6.6
28	16.2	32.9	37.3	385.8	267.8	97.0	7.0
29	18.0	36.1	40.4	421.2	284.0	101.5	7.3
TREE GRADE 1 3-1/2 LOGS							
16	0.0	5.1	8.5	60.0	129.2	70.0	4.6
17	.8	7.0	10.3	80.4	138.4	75.3	4.6
18	2.0	9.1	12.2	102.0	148.2	80.9	4.6
19	3.2	11.3	14.2	124.8	158.6	86.8	4.6
20	4.5	13.6	16.4	148.9	169.5	93.0	4.6
21	5.9	16.0	18.6	174.2	181.0	99.5	4.6
22	7.4	18.5	20.9	200.7	193.0	106.4	4.6
23	8.9	21.2	23.4	228.5	205.6	113.6	4.7
24	10.5	23.9	26.0	257.5	218.8	121.1	4.7
25	12.1	26.8	28.6	287.8	232.5	128.9	4.7
26	13.8	29.8	31.4	319.3	246.8	137.0	4.7

CONTINUED

Table 22.—Continued: YELLOW-POPLAR

Dbh (inches)	FAS	Selects	SAPS	No. 1C	No. 2A	No. 2B	No. 3C
TREE GRADE 1 4 LOGS							
16	0.0	6.8	8.5	62.2	141.3	84.7	5.8
17	1.2	8.8	10.3	82.5	150.4	92.6	5.6
18	2.4	11.0	12.2	103.9	160.0	101.0	5.4
19	3.7	13.3	14.2	126.6	170.1	109.9	5.1
20	5.1	15.7	16.4	150.6	180.9	119.3	4.9
21	6.6	18.2	18.6	175.7	192.1	129.1	4.7
22	8.1	20.9	20.9	202.1	203.9	139.5	4.4
23	9.7	23.7	23.4	229.7	216.3	150.3	4.1
24	11.4	26.6	26.0	258.5	229.2	161.6	3.8
25	13.1	29.6	28.6	288.6	242.6	173.3	3.6
26	14.9	32.8	31.4	319.8	256.6	185.6	3.2
TREE GRADE 2 2 LOGS							
13	0.0	0.0	4.0	4.4	68.5	21.5	0.2
14	.0	.5	4.8	18.8	73.5	23.2	.9
15	.2	1.1	5.7	34.1	78.9	25.0	1.7
16	.4	1.7	6.7	50.6	84.6	26.9	2.5
17	.6	2.4	7.8	68.1	90.8	28.9	3.4
18	.8	3.1	8.9	86.6	97.2	31.1	4.4
19	1.0	3.8	10.0	106.3	104.1	33.4	5.3
20	1.2	4.6	11.3	126.9	111.3	35.8	6.4
21	1.5	5.4	12.6	148.7	118.9	38.4	7.5
22	1.8	6.3	13.9	171.5	126.9	41.1	8.6
23	2.0	7.2	15.4	195.3	135.3	43.9	9.8
24	2.3	8.1	16.9	220.3	144.0	46.8	11.1
25	2.6	9.1	18.4	246.2	153.1	49.8	12.4
26	2.9	10.1	20.0	273.3	162.5	53.0	13.8
TREE GRADE 2 2-1/2 LOGS							
13	0.0	0.0	5.0	9.7	66.0	36.7	0.2
14	.0	.1	5.7	24.1	73.9	39.0	.9
15	.2	.9	6.5	39.5	82.5	41.4	1.7
16	.4	1.7	7.4	56.0	91.6	44.1	2.5
17	.6	2.5	8.4	73.6	101.4	46.9	3.4
18	.8	3.4	9.4	92.2	111.7	49.8	4.4
19	1.0	4.3	10.4	111.9	122.7	53.0	5.3
20	1.2	5.3	11.5	132.6	134.2	56.3	6.4
21	1.5	6.4	12.7	154.5	146.3	59.7	7.5
22	1.8	7.5	13.9	177.3	159.0	63.4	8.6
23	2.0	8.6	15.2	201.3	172.3	67.2	9.8
24	2.3	9.8	16.5	226.3	186.1	71.2	11.1
25	2.6	11.0	17.9	252.4	200.6	75.3	12.4
26	2.9	12.3	19.3	279.5	215.7	79.7	13.8
TREE GRADE 2 3 LOGS							
13	0.0	0.0	6.0	15.0	63.4	51.9	0.2
14	.0	.0	6.6	29.4	74.3	54.8	.9
15	.2	.6	7.4	44.9	86.1	57.9	1.7
16	.4	1.6	8.1	61.5	98.7	61.2	2.5
17	.6	2.6	9.0	79.1	112.0	64.8	3.4
18	.8	3.7	9.8	97.8	126.2	68.5	4.4
19	1.0	4.8	10.8	117.5	141.2	72.5	5.3
20	1.2	6.0	11.7	138.3	157.0	76.7	6.4
21	1.5	7.3	12.8	160.2	173.6	81.1	7.5
22	1.8	8.6	13.8	183.2	191.0	85.7	8.6
23	2.0	10.0	14.9	207.2	209.3	90.6	9.8
24	2.3	11.5	16.1	232.3	228.3	95.6	11.1
25	2.6	13.0	17.3	258.5	248.2	100.9	12.4
26	2.9	14.5	18.6	285.7	268.8	106.3	13.8

CONTINUED

Table 22.—Continued: YELLOW-POPLAR

Dbh (inches)	FAS	Selects	SAPS	No. 1C	No. 2A	No. 2B	No. 3C
			TREE GRADE 2 3-1/2 LOGS				
15	0.2	0.4	8.2	50.3	89.7	74.4	1.7
16	.4	1.5	8.9	66.9	105.7	78.4	2.5
17	.6	2.7	9.6	84.6	122.7	82.7	3.4
18	.8	4.0	10.3	103.3	140.7	87.3	4.4
19	1.0	5.3	11.1	123.2	159.7	92.1	5.3
20	1.2	6.8	12.0	144.0	179.8	97.1	6.4
21	1.5	8.2	12.8	166.0	200.9	102.5	7.5
22	1.8	9.8	13.8	189.1	223.1	108.0	8.6
23	2.0	11.4	14.7	213.2	246.3	113.9	9.8
24	2.3	13.1	15.7	238.4	270.5	120.0	11.1
25	2.6	14.9	16.8	264.6	295.7	126.4	12.4
26	2.9	16.8	17.9	291.9	322.0	133.0	13.8
			TREE GRADE 2 4 LOGS				
16	0.4	1.5	9.6	72.3	112.7	95.6	2.5
17	.6	2.9	10.2	90.1	133.3	100.6	3.4
18	.8	4.3	10.8	108.9	155.2	106.0	4.4
19	1.0	5.9	11.5	128.8	178.3	111.6	5.3
20	1.2	7.5	12.2	149.8	202.7	117.6	6.4
21	1.5	9.2	12.9	171.8	228.3	123.8	7.5
22	1.8	11.0	13.7	194.9	255.2	130.4	8.6
23	2.0	12.8	14.5	219.1	283.3	137.2	9.8
24	2.3	14.8	15.4	244.4	312.6	144.4	11.1
25	2.6	16.8	16.3	270.7	343.3	151.9	12.4
26	2.9	19.0	17.2	298.2	375.1	159.7	13.8
			TREE GRADE 3 1-1/2 LOGS				
10	0.0	1.3	0.4	0.0	28.6	0.0	6.2
11	.0	1.1	.6	.0	32.2	.0	6.4
12	.0	.8	.8	1.9	36.1	4.8	6.6
13	.0	.6	1.1	11.5	40.4	13.1	6.8
14	.0	.3	1.3	21.9	45.0	22.1	7.1
15	.0	.0	1.6	33.1	49.9	31.7	7.4
			TREE GRADE 3 2 LOGS				
10	0.0	1.0	0.4	0.0	21.2	12.0	6.2
11	.0	.9	.6	.0	26.7	18.6	6.4
12	.0	.8	.8	1.9	32.8	25.9	6.6
13	.0	.7	1.1	11.5	39.4	33.7	6.8
14	.0	.6	1.3	21.9	46.5	42.2	7.1
15	.0	.4	1.6	33.1	54.1	51.4	7.4
16	.0	.3	1.9	45.0	62.3	61.1	7.6
17	.0	.1	2.2	57.7	70.9	71.5	7.9
18	.0	.0	2.5	71.2	80.1	82.5	8.3
			TREE GRADE 3 2-1/2 LOGS				
12	0.0	0.8	0.8	1.9	29.4	46.9	6.6
13	.0	.8	1.1	11.5	38.3	54.4	6.8
14	.0	.9	1.3	21.9	47.9	62.4	7.1
15	.0	.9	1.6	33.1	58.3	71.0	7.4
16	.0	.9	1.9	45.0	69.3	80.3	7.6
17	.0	1.0	2.2	57.7	81.0	90.1	7.9
18	.0	1.0	2.5	71.2	93.5	100.5	8.3
19	.0	1.1	2.9	85.4	106.7	111.5	8.6
20	.0	1.1	3.2	100.4	120.5	123.1	9.0
21	.0	1.2	3.6	116.2	135.1	135.3	9.3

CONTINUED

Table 22.—Continued: YELLOW-POPLAR

Dbh (inches)	FAS	Selects	SAPS	No. 1C	No. 2A	No. 2B	No. 3C
TREE GRADE 3 3 LOGS							
13	0.0	1.0	1.1	11.5	37.3	75.0	6.8
14	.0	1.2	1.3	21.9	49.4	82.6	7.1
15	.0	1.4	1.6	33.1	62.4	90.7	7.4
16	.0	1.6	1.9	45.0	76.3	99.4	7.6
17	.0	1.9	2.2	57.7	91.1	108.6	7.9
18	.0	2.2	2.5	71.2	106.8	118.4	8.3
19	.0	2.4	2.9	85.4	123.4	128.8	8.6
20	.0	2.7	3.2	100.4	140.9	139.7	9.0
21	.0	3.0	3.6	116.2	159.3	151.2	9.3
22	.0	3.4	4.0	132.8	178.6	163.2	9.7
23	.0	3.7	4.4	150.1	198.8	175.8	10.1
24	.0	4.1	4.9	168.2	219.9	189.0	10.6
TREE GRADE 3 3-1/2 LOGS							
15	0.0	1.9	1.6	33.1	66.6	110.4	7.4
16	.0	2.3	1.9	45.0	83.4	118.5	7.6
17	.0	2.8	2.2	57.7	101.2	127.2	7.9
18	.0	3.3	2.5	71.2	120.2	136.4	8.3
19	.0	3.8	2.9	85.4	140.2	146.1	8.6
20	.0	4.3	3.2	100.4	161.3	156.3	9.0
21	.0	4.9	3.6	116.2	183.6	167.1	9.3
22	.0	5.5	4.0	132.8	206.8	178.4	9.7
23	.0	6.1	4.4	150.1	231.2	190.2	10.1
24	.0	6.8	4.9	168.2	256.7	202.6	10.6
TREE GRADE 3 4 LOGS							
15	0.0	2.4	1.6	33.1	70.7	130.1	7.4
16	.0	3.0	1.9	45.0	90.4	137.7	7.6
17	.0	3.7	2.2	57.7	111.3	145.8	7.9
18	.0	4.4	2.5	71.2	133.5	154.3	8.3
19	.0	5.1	2.9	85.4	157.0	163.4	8.6
20	.0	5.9	3.2	100.4	181.7	173.0	9.0
21	.0	6.8	3.6	116.2	207.8	183.0	9.3
22	.0	7.6	4.0	132.8	235.0	193.6	9.7
23	.0	8.6	4.4	150.1	263.6	204.6	10.1
24	.0	9.5	4.9	168.2	293.4	216.1	10.6

Table 23.—Lumber grade volume for NORTHERN RED OAK

[In board feet]

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 1 1-1/2 LOGS							
16	17.6	3.7	7.5	48.5	32.3	37.4	2.1
17	26.1	6.8	7.7	55.8	35.1	37.3	3.2
18	35.1	10.1	8.0	63.5	37.9	37.2	4.4
19	44.6	13.6	8.2	71.6	41.0	37.1	5.6
20	54.6	17.3	8.5	80.1	44.2	37.0	6.9
21	65.2	21.2	8.8	89.1	47.6	36.8	8.2
22	76.3	25.3	9.1	98.6	51.1	36.7	9.6
23	87.8	29.5	9.5	108.4	54.8	36.6	11.1
24	99.9	34.0	9.8	118.7	58.7	36.4	12.7
25	112.6	38.6	10.2	129.5	62.7	36.3	14.3
26	125.7	43.5	10.5	140.7	66.9	36.2	16.0
27	139.3	48.5	10.9	152.3	71.3	36.0	17.7
28	153.5	53.7	11.3	164.4	75.8	35.9	19.5
29	168.1	59.1	11.7	176.9	80.5	35.7	21.4
30	183.3	64.7	12.2	189.8	85.4	35.5	23.3
TREE GRADE 1 2 LOGS							
16	15.6	10.1	6.9	46.1	60.4	37.0	3.8
17	25.5	14.0	7.4	55.8	62.9	37.4	5.0
18	35.9	18.1	7.9	66.1	65.5	37.8	6.2
19	47.0	22.4	8.5	77.0	68.3	38.2	7.6
20	58.6	27.0	9.1	88.5	71.3	38.6	9.0
21	70.9	31.8	9.7	100.5	74.3	39.1	10.5
22	83.7	36.8	10.4	113.2	77.6	39.6	12.0
23	97.2	42.1	11.1	126.4	81.0	40.1	13.7
24	111.2	47.6	11.8	140.2	84.5	40.7	15.3
25	125.9	53.4	12.5	154.7	88.2	41.2	17.1
26	141.1	59.3	13.3	169.7	92.0	41.8	19.0
27	156.9	65.6	14.1	185.3	96.0	42.4	20.9
28	173.4	72.0	15.0	201.4	100.2	43.1	22.9
29	190.4	78.7	15.9	218.2	104.5	43.7	24.9
30	208.0	85.6	16.8	235.6	108.9	44.4	27.0
31	226.2	92.8	17.7	253.5	113.5	45.1	29.3
32	245.1	100.1	18.7	272.1	118.3	45.8	31.5
33	264.5	107.8	19.7	291.2	123.2	46.6	33.9
34	284.5	115.6	20.7	310.9	128.2	47.3	36.3
35	305.1	123.7	21.8	331.2	133.4	48.1	38.8
TREE GRADE 1 2-1/2 LOGS							
16	13.6	16.5	6.2	43.6	88.5	36.6	5.5
17	24.9	21.2	7.0	55.8	90.7	37.4	6.8
18	36.8	26.1	7.8	68.7	93.1	38.4	8.1
19	49.4	31.2	8.7	82.4	95.6	39.3	9.6
20	62.6	36.7	9.6	96.8	98.3	40.3	11.1
21	76.6	42.4	10.6	111.9	101.1	41.4	12.7
22	91.2	48.4	11.6	127.8	104.0	42.5	14.4
23	106.5	54.7	12.7	144.4	107.1	43.7	16.2
24	122.5	61.3	13.8	161.7	110.3	44.9	18.0
25	139.2	68.1	14.9	179.8	113.7	46.1	20.0
26	156.5	75.2	16.1	198.6	117.1	47.5	22.0
27	174.5	82.7	17.4	218.2	120.8	48.8	24.1
28	193.3	90.3	18.7	238.5	124.5	50.3	26.2
29	212.6	98.3	20.0	259.5	128.4	51.7	28.5
30	232.7	106.6	21.4	281.3	132.4	53.3	30.8
31	253.5	115.1	22.8	303.8	136.6	54.8	33.2
32	274.9	123.9	24.3	327.1	140.9	56.5	35.6
33	297.0	133.0	25.8	351.1	145.3	58.1	38.2
34	319.8	142.3	27.4	375.8	149.9	59.9	40.8
35	343.3	152.0	29.0	401.3	154.6	61.7	43.5

Continued

Table 23.—Continued: NORTHERN RED OAK

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 1 3 LOGS							
16	11.7	23.0	5.6	41.2	116.5	36.2	7.1
17	24.3	28.3	6.7	55.8	118.6	37.5	8.5
18	37.6	34.0	7.8	71.4	120.7	38.9	10.0
19	51.7	40.0	9.0	87.8	123.0	40.4	11.6
20	66.6	46.4	10.2	105.1	125.4	42.0	13.3
21	82.3	53.0	11.5	123.3	127.9	43.7	15.0
22	98.7	60.0	12.8	142.4	130.5	45.4	16.8
23	115.8	67.3	14.3	162.4	133.3	47.2	18.7
24	133.8	74.9	15.8	183.2	136.1	49.1	20.7
25	152.5	82.9	17.3	205.0	139.1	51.1	22.8
26	171.9	91.1	18.9	227.6	142.2	53.1	25.0
27	192.2	99.7	20.6	251.1	145.5	55.2	27.2
28	213.1	108.7	22.3	275.6	148.9	57.4	29.6
29	234.9	117.9	24.1	300.9	152.3	59.7	32.0
30	257.4	127.5	26.0	327.1	156.0	62.1	34.5
31	280.7	137.4	27.9	354.1	159.7	64.6	37.1
32	304.7	147.6	29.9	382.1	163.5	67.1	39.8
33	329.5	158.2	32.0	411.0	167.5	69.7	42.5
34	355.1	169.0	34.1	440.7	171.6	72.4	45.4
35	381.4	180.2	36.3	471.3	175.8	75.2	48.3
TREE GRADE 1 3-1/2 LOGS							
20	70.6	56.0	10.7	113.4	152.4	43.7	15.4
21	88.0	63.6	12.4	134.7	154.6	45.9	17.3
22	106.1	71.6	14.1	157.0	157.0	48.3	19.2
23	125.2	79.9	15.9	180.3	159.4	50.7	21.3
24	145.1	88.6	17.7	204.7	161.9	53.3	23.4
25	165.8	97.6	19.7	230.1	164.6	56.0	25.7
26	187.4	107.0	21.7	256.6	167.3	58.8	28.0
27	209.8	116.8	23.8	284.1	170.2	61.6	30.4
28	233.0	127.0	26.0	312.6	173.2	64.6	32.9
29	257.1	137.5	28.3	342.2	176.3	67.8	35.5
30	282.1	148.4	30.6	372.8	179.5	71.0	38.2
31	307.9	159.7	33.1	404.4	182.8	74.3	41.0
32	334.6	171.4	35.6	437.1	186.2	77.8	43.9
33	362.0	183.4	38.2	470.8	189.7	81.3	46.8
34	390.4	195.7	40.8	505.6	193.3	85.0	49.9
35	419.6	208.5	43.6	541.4	197.1	88.7	53.0
TREE GRADE 1 4 LOGS							
20	74.6	65.7	11.3	121.7	179.5	45.4	17.5
21	93.6	74.2	13.3	146.1	181.4	48.2	19.5
22	113.6	83.1	15.3	171.6	183.4	51.2	21.6
23	134.5	92.5	17.5	198.3	185.5	54.3	23.8
24	156.3	102.2	19.7	226.2	187.7	57.5	26.1
25	179.1	112.4	22.1	255.3	190.0	60.9	28.5
26	202.8	122.9	24.5	285.6	192.4	64.4	31.0
27	227.4	133.9	27.1	317.0	194.9	68.1	33.6
28	252.9	145.3	29.7	349.7	197.5	71.8	36.3
29	279.4	157.1	32.4	383.5	200.2	75.8	39.0
30	306.8	169.4	35.3	418.5	203.0	79.8	41.9
31	335.1	182.0	38.2	454.7	205.9	84.1	44.9
32	364.4	195.1	41.2	492.1	208.8	88.4	48.0
33	394.6	208.6	44.3	530.7	211.9	92.9	51.2
34	425.7	222.5	47.5	570.5	215.0	97.5	54.4
35	457.7	236.8	50.8	611.4	218.3	102.3	57.8

CONTINUED

Table 23.—Continued: NORTHERN RED OAK

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
TREE GRADE 2 1-1/2 LOGS							
13	0.0	18.3	3.7	11.3	22.2	12.9	5.7
14	.0	19.0	3.7	17.5	25.5	14.7	6.1
15	.0	19.8	3.7	24.1	29.0	16.6	6.5
16	1.0	20.6	3.7	31.1	32.7	18.7	7.0
17	5.0	21.4	3.7	38.6	36.7	20.9	7.5
18	9.3	22.3	3.7	46.6	40.9	23.3	8.0
19	13.8	23.3	3.7	55.0	45.4	25.8	8.6
20	18.6	24.3	3.7	63.9	50.1	28.4	9.2
21	23.6	25.3	3.7	73.2	55.1	31.1	9.8
22	28.8	26.5	3.7	83.0	60.3	34.0	10.4
23	34.3	27.6	3.7	93.3	65.7	37.1	11.1
24	40.1	28.8	3.7	104.0	71.4	40.2	11.8
25	46.1	30.1	3.7	115.1	77.3	43.5	12.6
26	52.3	31.4	3.7	126.8	83.5	46.9	13.3
27	58.8	32.8	3.7	138.8	89.9	50.5	14.1
28	65.5	34.2	3.7	151.3	96.5	54.2	15.0
29	72.4	35.7	3.7	164.3	103.4	58.0	15.8
30	79.6	37.2	3.7	177.8	110.5	62.0	16.7
TREE GRADE 2 2 LOGS							
13	0.0	15.5	3.7	16.3	43.1	28.8	6.5
14	1.3	17.0	3.7	24.3	46.5	30.2	7.1
15	4.8	18.6	3.7	33.0	50.2	31.6	7.7
16	8.6	20.4	3.7	42.2	54.2	33.2	8.4
17	12.7	22.3	3.7	52.1	58.4	34.9	9.1
18	16.9	24.2	3.7	62.5	62.9	36.6	9.8
19	21.4	26.3	3.7	73.6	67.6	38.5	10.6
20	26.2	28.5	3.7	85.2	72.6	40.4	11.4
21	31.2	30.8	3.7	97.5	77.8	42.5	12.2
22	36.5	33.3	3.7	110.3	83.3	44.6	13.1
23	42.0	35.8	3.7	123.7	89.1	46.9	14.1
24	47.7	38.5	3.7	137.8	95.1	49.3	15.1
25	53.7	41.2	3.7	152.4	101.4	51.7	16.1
26	59.9	44.1	3.7	167.6	107.9	54.3	17.2
27	66.4	47.1	3.7	183.4	114.7	56.9	18.3
28	73.1	50.2	3.7	199.9	121.7	59.7	19.4
29	80.1	53.4	3.7	216.9	129.0	62.6	20.6
30	87.3	56.8	3.7	234.5	136.5	65.5	21.8
TREE GRADE 2 2-1/2 LOGS							
13	5.6	12.6	3.7	21.2	63.9	44.8	7.4
14	8.9	15.0	3.7	31.2	67.6	45.7	8.1
15	12.5	17.5	3.7	41.9	71.5	46.6	8.9
16	16.3	20.2	3.7	53.3	75.7	47.7	9.7
17	20.3	23.1	3.7	65.5	80.1	48.8	10.6
18	24.6	26.1	3.7	78.5	84.8	49.9	11.6
19	29.1	29.4	3.7	92.1	89.8	51.2	12.5
20	33.8	32.8	3.7	106.5	95.1	52.5	13.6
21	38.9	36.3	3.7	121.7	100.6	53.8	14.7
22	44.1	40.1	3.7	137.6	106.4	55.2	15.8
23	49.6	44.0	3.7	154.2	112.5	56.7	17.0
24	55.3	48.1	3.7	171.5	118.8	58.3	18.3
25	61.3	52.4	3.7	189.6	125.4	59.9	19.6
26	67.6	56.8	3.7	208.5	132.3	61.6	21.0
27	74.0	61.4	3.7	228.1	139.4	63.4	22.4
28	80.7	66.2	3.7	248.4	146.9	65.2	23.9
29	87.7	71.2	3.7	269.4	154.6	67.1	25.4
30	94.9	76.3	3.7	291.2	162.5	69.0	27.0

CONTINUED

Table 23.—Continued: NORTHERN RED OAK

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
			TREE GRADE 2 3 LOGS				
18	32.2	28.1	3.7	94.4	106.8	63.3	13.3
19	36.7	32.4	3.7	110.7	112.0	63.9	14.5
20	41.5	37.0	3.7	127.8	117.6	64.5	15.8
21	46.5	41.8	3.7	145.9	123.4	65.1	17.1
22	51.7	46.9	3.7	164.8	129.5	65.8	18.5
23	57.2	52.2	3.7	184.6	135.9	66.6	20.0
24	63.0	57.8	3.7	205.3	142.5	67.3	21.6
25	69.0	63.5	3.7	226.9	149.5	68.1	23.1
26	75.2	69.5	3.7	249.3	156.7	68.9	24.8
27	81.7	75.8	3.7	272.7	164.2	69.8	26.5
28	88.4	82.3	3.7	296.9	172.0	70.7	28.3
29	95.4	89.0	3.7	322.0	180.1	71.6	30.2
30	102.6	95.9	3.7	347.9	188.5	72.6	32.1
31	110.0	103.1	3.7	374.8	197.2	73.5	34.1
32	117.7	110.5	3.7	402.5	206.1	74.6	36.2
33	125.6	118.2	3.7	431.1	215.3	75.6	38.3
34	133.8	126.1	3.7	460.6	224.8	76.7	40.5
35	142.3	134.2	3.7	491.0	234.6	77.8	42.7
			TREE GRADE 3 1 LOG				
10	1.1	0.0	2.0	0.0	4.7	13.9	9.1
11	1.1	.0	2.0	2.1	9.4	15.4	9.9
12	1.2	.2	2.0	7.0	14.5	17.2	10.8
13	1.3	1.1	2.0	12.3	20.1	19.1	11.7
14	1.3	2.1	2.0	18.0	26.1	21.1	12.7
15	1.4	3.1	2.0	24.2	32.6	23.3	13.8
16	1.5	4.2	2.0	30.8	39.5	25.7	15.0
			TREE GRADE 3 1-1/2 LOGS				
10	0.0	0.0	2.0	0.0	6.7	23.6	17.9
11	.1	.0	2.0	1.9	11.4	25.3	19.0
12	.4	.8	2.0	6.9	16.7	27.2	20.3
13	.8	1.8	2.0	12.3	22.3	29.2	21.7
14	1.2	2.9	2.0	18.2	28.5	31.4	23.3
15	1.7	4.1	2.0	24.5	35.0	33.8	24.9
16	2.1	5.3	2.0	31.2	42.1	36.3	26.6
17	2.6	6.7	2.0	38.3	49.5	39.0	28.5
18	3.2	8.1	2.0	45.9	57.5	41.9	30.5
19	3.7	9.6	2.0	54.0	65.9	44.9	32.5
20	4.3	11.2	2.0	62.4	74.7	48.1	34.7
21	5.0	12.8	2.0	71.3	84.0	51.4	37.0
22	5.6	14.5	2.0	80.6	93.7	55.0	39.4
23	6.3	16.4	2.0	90.4	103.9	58.6	42.0
24	7.0	18.2	2.0	100.6	114.6	62.5	44.6
25	7.8	20.2	2.0	111.2	125.7	66.5	47.4

CONTINUED

Table 23.—Continued: NORTHERN RED OAK

TREE GRADE 3
2 LOGS

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
10	0.0	0.0	2.0	0.0	8.7	33.3	26.6
11	.0	.5	2.0	1.8	13.5	35.2	28.1
12	.0	1.5	2.0	6.8	18.8	37.2	29.9
13	.3	2.6	2.0	12.4	24.6	39.4	31.7
14	1.1	3.8	2.0	18.3	30.8	41.7	33.8
15	1.9	5.1	2.0	24.7	37.4	44.3	35.9
16	2.8	6.5	2.0	31.5	44.6	47.0	38.3
17	3.7	7.9	2.0	38.8	52.2	49.9	40.7
18	4.6	9.5	2.0	46.5	60.2	52.9	43.4
19	5.7	11.1	2.0	54.7	68.7	56.2	46.1
20	6.8	12.8	2.0	63.3	77.7	59.6	49.0
21	7.9	14.7	2.0	72.3	87.1	63.2	52.1
22	9.1	16.6	2.0	81.8	97.0	67.0	55.3
23	10.4	18.6	2.0	91.7	107.3	70.9	58.7
24	11.7	20.6	2.0	102.1	118.1	75.0	62.2
25	13.0	22.8	2.0	112.9	129.4	79.3	65.9

TREE GRADE 3
2-1/2 LOGS

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
14	1.0	4.7	2.0	18.4	33.1	52.0	44.3
15	2.1	6.1	2.0	24.9	39.9	54.7	47.0
16	3.4	7.6	2.0	31.9	47.1	57.6	49.9
17	4.7	9.2	2.0	39.3	54.8	60.7	53.0
18	6.1	10.9	2.0	47.1	62.9	64.0	56.3
19	7.6	12.6	2.0	55.4	71.6	67.5	59.7
20	9.2	14.5	2.0	64.2	80.7	71.1	63.4
21	10.8	16.5	2.0	73.3	90.2	75.0	67.2
22	12.6	18.6	2.0	83.0	100.2	79.0	71.2
23	14.4	20.8	2.0	93.1	110.7	83.2	75.5
24	16.3	23.0	2.0	103.6	121.7	87.6	79.9
25	18.3	25.4	2.0	114.6	133.1	92.2	84.4

TREE GRADE 3
3 LOGS

Dbh (inches)	FAS	FAS1F	Select	No. 1C	No. 2C	No. 3A	No. 3B
16	4.0	8.7	2.0	32.2	49.6	68.3	61.5
17	5.8	10.4	2.0	39.8	57.4	71.6	65.2
18	7.6	12.2	2.0	47.7	65.7	75.1	69.2
19	9.6	14.2	2.0	56.1	74.4	78.7	73.3
20	11.6	16.2	2.0	65.0	83.6	82.6	77.7
21	13.8	18.4	2.0	74.4	93.3	86.7	82.3
22	16.0	20.6	2.0	84.1	103.5	91.0	87.1
23	18.4	23.0	2.0	94.4	114.1	95.5	92.2
24	20.9	25.4	2.0	105.1	125.2	100.1	97.5
25	23.5	28.0	2.0	116.3	136.8	105.0	103.0

Table 24.—Lumber grade volume for CHESTNUT OAK

[In board feet]

TREE GRADE 1
1-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
16	6.8	0.0	3.2	2.8	3.2	1.3
17	7.7	2.2	4.9	4.0	3.2	1.3
18	8.6	6.9	6.7	5.4	3.2	1.3
19	9.5	11.8	8.6	6.8	3.2	1.3
20	10.6	17.0	10.6	8.3	3.2	1.3
21	11.6	22.5	12.7	9.9	3.2	1.3
22	12.7	28.2	14.8	11.6	3.2	1.3
23	13.9	34.2	17.1	13.3	3.2	1.3
24	15.1	40.4	19.5	15.1	3.2	1.3

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
16	18.1	7.3	28.8	15.1	20.0	15.3
17	21.2	12.9	28.2	16.1	22.7	22.4
18	24.4	18.9	27.6	17.1	25.4	30.0
19	27.8	25.2	26.9	18.2	28.4	38.0
20	31.4	31.8	26.1	19.3	31.5	46.4
21	35.2	38.8	25.4	20.5	34.8	55.3
22	39.2	46.1	24.6	21.8	38.2	64.5
23	43.4	53.7	23.7	23.1	41.8	74.3
24	47.7	61.7	22.9	24.5	45.5	84.4

TREE GRADE 1
2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
16	6.0	5.3	6.1	2.8	3.2	1.3
17	7.6	9.7	7.8	4.0	3.2	1.3
18	9.4	14.4	9.6	5.4	3.2	1.3
19	11.3	19.3	11.5	6.8	3.2	1.3
20	13.2	24.5	13.5	8.3	3.2	1.3
21	15.3	29.9	15.6	9.9	3.2	1.3
22	17.5	35.6	17.8	11.6	3.2	1.3
23	19.7	41.6	20.1	13.3	3.2	1.3
24	22.1	47.8	22.5	15.1	3.2	1.3
25	24.6	54.3	25.0	17.0	3.2	1.3
26	27.2	61.1	27.6	19.0	3.2	1.3
27	29.8	68.1	30.3	21.0	3.2	1.3

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
16	19.4	11.1	30.0	27.7	24.0	15.3
17	23.0	17.5	29.9	29.0	26.6	22.4
18	26.8	24.3	29.8	30.2	29.4	30.0
19	30.8	31.4	29.7	31.6	32.3	38.0
20	35.0	39.0	29.6	33.0	35.4	46.4
21	39.5	46.9	29.5	34.5	38.7	55.3
22	44.2	55.2	29.4	36.1	42.1	64.5
23	49.0	63.9	29.3	37.7	45.7	74.3
24	54.1	73.0	29.2	39.4	49.4	84.4
25	59.5	82.5	29.0	41.2	53.3	95.0
26	65.0	92.4	28.9	43.1	57.4	106.0
27	70.7	102.6	28.8	45.0	61.6	117.5

CONTINUED

Table 24.—Continued: CHESTNUT OAK

TREE GRADE 1
2-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
16	5.1	12.9	9.1	2.8	3.2	1.3
17	7.5	17.2	10.7	4.0	3.2	1.3
18	10.2	21.9	12.5	5.4	3.2	1.3
19	13.0	26.8	14.4	6.8	3.2	1.3
20	15.9	31.9	16.4	8.3	3.2	1.3
21	19.0	37.3	18.5	9.9	3.2	1.3
22	22.2	43.0	20.7	11.6	3.2	1.3
23	25.6	49.0	23.0	13.3	3.2	1.3
24	29.2	55.2	25.4	15.1	3.2	1.3
25	32.8	61.7	27.9	17.0	3.2	1.3
26	36.7	68.5	30.5	19.0	3.2	1.3
27	40.7	75.5	33.2	21.0	3.2	1.3

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
16	20.7	14.9	31.1	40.4	27.9	15.3
17	24.8	22.1	31.5	41.8	30.5	22.4
18	29.2	29.7	32.0	43.4	33.3	30.0
19	33.8	37.7	32.5	45.0	36.3	38.0
20	38.7	46.1	33.1	46.7	39.4	46.4
21	43.8	55.0	33.6	48.5	42.6	55.3
22	49.1	64.4	34.2	50.4	46.1	64.5
23	54.7	74.1	34.8	52.4	49.7	74.3
24	60.6	84.3	35.5	54.4	53.4	84.4
25	66.7	94.9	36.1	56.6	57.3	95.0
26	73.0	106.0	36.8	58.8	61.4	106.0
27	79.7	117.4	37.6	61.2	65.6	117.5

TREE GRADE 1
3 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
16	4.2	20.4	12.0	2.8	3.2	1.3
17	7.5	24.7	13.7	4.0	3.2	1.3
18	11.0	29.3	15.5	5.4	3.2	1.3
19	14.7	34.2	17.3	6.8	3.2	1.3
20	18.6	39.4	19.3	8.3	3.2	1.3
21	22.7	44.8	21.4	9.9	3.2	1.3
22	27.0	50.5	23.6	11.6	3.2	1.3
23	31.5	56.4	25.9	13.3	3.2	1.3
24	36.2	62.6	28.3	15.1	3.2	1.3
25	41.1	69.1	30.8	17.0	3.2	1.3
26	46.2	75.8	33.4	19.0	3.2	1.3
27	51.5	82.8	36.1	21.0	3.2	1.3

CONTINUED

Table 24.—Continued: CHESTNUT OAK

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
16	22.0	18.7	32.2	53.0	31.9	15.3
17	26.7	26.7	33.2	54.7	34.5	22.4
18	31.6	35.1	34.2	56.5	37.3	30.0
19	36.8	44.0	35.3	58.4	40.2	38.0
20	42.3	53.3	36.5	60.4	43.3	46.4
21	48.0	63.2	37.7	62.5	46.6	55.3
22	54.1	73.5	39.0	64.7	50.0	64.5
23	60.4	84.3	40.4	67.0	53.6	74.3
24	67.0	95.6	41.8	69.4	57.3	84.4
25	73.9	107.3	43.2	71.9	61.2	95.0
26	81.1	119.6	44.7	74.6	65.3	106.0
27	88.6	132.3	46.3	77.3	69.5	117.5

TREE GRADE 1
3-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
20	21.3	46.8	22.3	8.3	3.2	1.3
21	26.4	52.2	24.3	9.9	3.2	1.3
22	31.7	57.9	26.5	11.6	3.2	1.3
23	37.4	63.8	28.8	13.3	3.2	1.3
24	43.2	70.0	31.2	15.1	3.2	1.3
25	49.4	76.4	33.7	17.0	3.2	1.3
26	55.7	83.2	36.3	19.0	3.2	1.3
27	62.3	90.1	39.0	21.0	3.2	1.3

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
20	45.9	60.5	40.0	74.1	47.3	46.4
21	52.3	71.3	41.9	76.5	50.5	55.3
22	59.1	82.6	43.8	79.0	54.0	64.5
23	66.1	94.5	45.9	81.7	57.5	74.3
24	73.5	106.8	48.1	84.4	61.3	84.4
25	81.2	119.8	50.3	87.3	65.2	95.0
26	89.2	133.2	52.7	90.3	69.3	106.0
27	97.5	147.1	55.1	93.4	73.5	117.5

TREE GRADE 2
1 LOG

Dbh (Inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
13	0.0	0.0	0.0	4.6	9.0	0.0
14	.0	.0	.4	4.7	8.1	.0
15	.0	1.2	1.6	4.9	7.2	.0
16	.0	5.3	2.9	5.0	6.2	.0
17	.0	9.6	4.3	5.2	5.1	.0
18	.0	14.3	5.8	5.4	3.9	.0
19	.0	19.1	7.4	5.6	2.7	.0
20	.0	24.3	9.1	5.8	1.5	.3
21	.0	29.7	10.8	6.1	.2	.5
22	.0	35.4	12.7	6.3	.0	.8

CONTINUED

Table 24.—Continued: CHESTNUT OAK

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
13	17.9	2.6	7.0	0.0	26.9	4.3
14	17.3	6.0	7.8	.0	26.7	9.0
15	16.7	9.7	8.6	.3	26.4	13.9
16	16.0	13.7	9.5	1.1	26.2	19.2
17	15.3	17.9	10.4	2.0	25.9	24.9
18	14.5	22.3	11.4	3.0	25.6	30.9
19	13.7	27.0	12.4	3.9	25.3	37.3
20	12.8	31.9	13.5	5.0	24.9	44.0
21	11.9	37.1	14.7	6.1	24.5	51.0
22	11.0	42.6	15.9	7.2	24.2	58.4

TREE GRADE 2
1-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
13	1.5	0.0	0.0	2.4	6.7	0.0
14	1.5	.0	.4	2.9	6.1	.0
15	1.5	1.2	1.6	3.4	5.5	.0
16	1.4	5.3	2.9	4.0	4.9	.0
17	1.3	9.6	4.3	4.5	4.3	.0
18	1.3	14.3	5.8	5.1	3.6	.2
19	1.2	19.1	7.4	5.8	2.8	.4
20	1.2	24.3	9.1	6.5	2.0	.7
21	1.1	29.7	10.8	7.2	1.2	.9
22	1.0	35.4	12.7	7.9	.3	1.2
23	1.0	41.3	14.6	8.7	.0	1.5
24	.9	47.5	16.6	9.6	.0	1.7
25	.8	54.0	18.7	10.4	.0	2.0
26	.7	60.7	20.9	11.3	.0	2.4

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
13	16.9	1.9	12.4	11.7	29.0	9.5
14	16.8	6.2	13.1	12.5	29.2	14.2
15	16.6	10.7	13.7	13.2	29.5	19.1
16	16.4	15.6	14.4	14.1	29.7	24.5
17	16.2	20.9	15.2	14.9	30.0	30.1
18	16.0	26.4	16.0	15.9	30.3	36.1
19	15.8	32.2	16.9	16.9	30.6	42.5
20	15.6	38.4	17.7	17.9	30.9	49.2
21	15.4	44.9	18.7	19.0	31.2	56.2
22	15.1	51.7	19.7	20.1	31.5	63.6
23	14.9	58.8	20.7	21.3	31.9	71.3
24	14.6	66.2	21.8	22.6	32.3	79.4
25	14.3	74.0	22.9	23.9	32.7	87.8
26	14.0	82.0	24.1	25.3	33.1	96.5

CONTINUED

Table 24.—Continued: CHESTNUT OAK

TREE GRADE 2
2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
13	3.1	0.0	0.0	0.3	4.3	0.0
14	3.1	.0	.4	1.1	4.1	.0
15	3.0	1.2	1.6	1.9	3.9	.0
16	3.0	5.3	2.9	2.9	3.7	.2
17	3.0	9.6	4.3	3.8	3.4	.4
18	2.9	14.3	5.8	4.9	3.2	.6
19	2.9	19.1	7.4	6.0	2.9	.8
20	2.8	24.3	9.1	7.1	2.6	1.0
21	2.8	29.7	10.8	8.3	2.3	1.3
22	2.7	35.4	12.7	9.6	1.9	1.5
23	2.7	41.3	14.6	10.9	1.6	1.8
24	2.6	47.5	16.6	12.3	1.2	2.1
25	2.6	54.0	18.7	13.7	.9	2.3
26	2.5	60.7	20.9	15.2	.5	2.6
27	2.5	67.7	23.1	16.8	.1	3.0
28	2.4	75.0	25.5	18.4	.0	3.3
29	2.4	82.5	27.9	20.1	.0	3.6
30	2.3	90.3	30.4	21.8	.0	4.0

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
13	16.0	1.1	17.9	24.6	31.1	14.8
14	16.3	6.3	18.4	25.4	31.7	19.4
15	16.6	11.7	18.9	26.1	32.5	24.4
16	16.9	17.6	19.4	27.0	33.2	29.7
17	17.2	23.9	20.0	27.8	34.1	35.3
18	17.6	30.5	20.6	28.8	34.9	41.3
19	18.0	37.5	21.3	29.8	35.9	47.7
20	18.4	44.9	22.0	30.8	36.8	54.4
21	18.8	52.6	22.7	31.9	37.9	61.4
22	19.3	60.8	23.5	33.0	38.9	68.8
23	19.7	69.3	24.3	34.2	40.0	76.5
24	20.2	78.2	25.1	35.5	41.2	84.6
25	20.7	87.5	26.0	36.8	42.4	93.0
26	21.3	97.1	26.9	38.2	43.7	101.7
27	21.8	107.2	27.8	39.6	45.0	110.8
28	22.4	117.6	28.8	41.0	46.4	120.3
29	23.0	128.4	29.8	42.6	47.8	130.0
30	23.6	139.5	30.8	44.1	49.3	140.2

Continued

Table 24.—Continued: CHESTNUT OAK

TREE GRADE 2
2-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
13	4.6	0.0	0.0	0.0	2.0	0.1
14	4.6	.0	.4	.0	2.1	.3
15	4.6	1.2	1.6	.5	2.3	.4
16	4.6	5.3	2.9	1.8	2.4	.6
17	4.6	9.6	4.3	3.1	2.6	.8
18	4.6	14.3	5.8	4.6	2.8	1.0
19	4.5	19.1	7.4	6.1	2.9	1.2
20	4.5	24.3	9.1	7.7	3.1	1.4
21	4.5	29.7	10.8	9.4	3.3	1.6
22	4.5	35.4	12.7	11.2	3.5	1.9
23	4.4	41.3	14.6	13.1	3.7	2.1
24	4.4	47.5	16.6	15.0	4.0	2.4
25	4.4	54.0	18.7	17.0	4.2	2.7
26	4.3	60.7	20.9	19.1	4.4	2.9
27	4.3	67.7	23.1	21.3	4.7	3.2
28	4.3	75.0	25.5	23.6	5.0	3.5
29	4.2	82.5	27.9	26.0	5.2	3.8
30	4.2	90.3	30.4	28.4	5.5	4.2

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
13	15.0	0.4	23.3	37.6	33.1	20.0
14	15.7	6.4	23.7	38.3	34.3	24.6
15	16.5	12.8	24.0	39.0	35.5	29.6
16	17.3	19.6	24.4	39.9	36.8	34.9
17	18.2	26.9	24.8	40.8	38.2	40.6
18	19.1	34.6	25.3	41.7	39.6	46.6
19	20.1	42.8	25.7	42.7	41.2	52.9
20	21.2	51.4	26.2	43.7	42.8	59.6
21	22.2	60.4	26.7	44.8	44.5	66.6
22	23.4	69.9	27.3	46.0	46.3	74.0
23	24.6	79.8	27.8	47.2	48.2	81.7
24	25.8	90.2	28.4	48.4	50.1	89.8
25	27.1	101.0	29.0	49.7	52.2	98.2
26	28.5	112.2	29.6	51.1	54.3	107.0
27	29.9	123.9	30.3	52.5	56.5	116.0
28	31.4	136.0	31.0	54.0	58.8	125.5
29	32.9	148.6	31.7	55.5	61.2	135.3
30	34.4	161.6	32.4	57.0	63.7	145.4

CONTINUED

Table 24.—Continued: CHESTNUT OAK

TREE GRADE 2
3 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
13	6.2	0.0	0.0	0.0	0.0	0.6
14	6.2	.0	.4	.0	.2	.7
15	6.2	1.2	1.6	.0	.7	.9
16	6.2	5.3	2.9	.7	1.2	1.0
17	6.2	9.6	4.3	2.4	1.8	1.2
18	6.2	14.3	5.8	4.3	2.4	1.4
19	6.2	19.1	7.4	6.3	3.0	1.6
20	6.2	24.3	9.1	8.4	3.7	1.8
21	6.2	29.7	10.8	10.5	4.4	2.0
22	6.2	35.4	12.7	12.8	5.1	2.2
23	6.2	41.3	14.6	15.2	5.9	2.5
24	6.2	47.5	16.6	17.7	6.7	2.7
25	6.2	54.0	18.7	20.3	7.5	3.0
26	6.1	60.7	20.9	23.1	8.4	3.2
27	6.1	67.7	23.1	25.9	9.3	3.5
28	6.1	75.0	25.5	28.8	10.3	3.8
29	6.1	82.5	27.9	31.9	11.2	4.1
30	6.1	90.3	30.4	35.0	12.3	4.4

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
13	14.1	0.0	28.8	50.5	35.2	25.2
14	15.2	6.5	29.0	51.2	36.8	29.8
15	16.5	13.8	29.2	52.0	38.5	34.8
16	17.8	21.6	29.4	52.8	40.3	40.1
17	19.2	29.9	29.6	53.7	42.2	45.8
18	20.7	38.7	29.9	54.6	44.3	51.8
19	22.3	48.0	30.2	55.6	46.5	58.1
20	23.9	57.8	30.4	56.6	48.8	64.8
21	25.7	68.1	30.7	57.7	51.2	71.8
22	27.5	79.0	31.0	58.9	53.7	79.2
23	29.5	90.3	31.4	60.1	56.3	86.9
24	31.5	102.1	31.7	61.3	59.1	95.0
25	33.6	114.5	32.1	62.6	61.9	103.4
26	35.7	127.3	32.4	64.0	64.9	112.2
27	38.0	140.6	32.8	65.4	68.0	121.3
28	40.4	154.5	33.2	66.9	71.3	130.7
29	42.8	168.8	33.6	68.4	74.6	140.5
30	45.3	183.7	34.0	70.0	78.1	150.6

TREE GRADE 3
1 LOG

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
10	0.0	0.0	0.0	0.0	1.1	0.4
11	.0	.0	.0	.0	1.1	.4
12	.0	.0	.1	.0	1.1	.4
13	.0	1.0	.2	.0	1.1	.4
14	.0	2.2	.3	.0	1.1	.4
15	.0	3.4	.4	.0	1.1	.4
16	.0	4.8	.5	.3	1.1	.4
17	.0	6.3	.7	.8	1.1	.4
18	.0	7.8	.8	1.3	1.1	.4
19	.0	9.4	1.0	1.8	1.1	.4
20	.0	11.2	1.1	2.4	1.1	.4

CONTINUED

Table 24.—Continued: CHESTNUT OAK

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
10	4.1	3.3	2.4	5.4	4.4	10.3
11	3.6	5.2	3.1	5.8	5.7	12.5
12	3.0	7.2	3.8	6.1	7.2	15.0
13	2.3	9.3	4.6	6.5	8.8	17.6
14	1.6	11.7	5.4	7.0	10.5	20.4
15	.8	14.2	6.3	7.4	12.3	23.5
16	.0	16.9	7.3	7.9	14.3	26.8
17	.0	19.8	8.3	8.5	16.3	30.2
18	.0	22.8	9.4	9.0	18.6	33.9
19	.0	26.0	10.5	9.6	20.9	37.8
20	.0	29.4	11.7	10.3	23.4	41.9

TREE GRADE 3
1-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
10	0.0	0.0	0.0	0.0	1.1	0.4
11	.0	.0	.0	.0	1.1	.4
12	.0	.0	.0	.0	1.1	.4
13	.0	1.0	.1	.0	1.1	.4
14	.0	2.2	.3	.0	1.1	.4
15	.0	3.4	.5	.4	1.1	.4
16	.0	4.8	.7	.8	1.1	.4
17	.0	6.3	.9	1.3	1.1	.4
18	.0	7.8	1.1	1.8	1.1	.4
19	.0	9.4	1.4	2.4	1.1	.4
20	.0	11.2	1.6	2.9	1.1	.4
21	.0	13.0	1.9	3.5	1.1	.4
22	.0	14.9	2.2	4.1	1.1	.4
23	.0	16.9	2.5	4.8	1.1	.4
24	.0	18.9	2.8	5.5	1.1	.4

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
10	4.1	0.0	5.5	11.0	13.2	9.4
11	4.2	.4	6.1	12.0	14.5	13.0
12	4.2	3.3	6.8	13.0	15.8	16.9
13	4.3	6.5	7.6	14.1	17.3	21.1
14	4.4	9.9	8.4	15.3	18.9	25.6
15	4.5	13.5	9.3	16.6	20.6	30.5
16	4.6	17.4	10.3	17.9	22.5	35.7
17	4.7	21.6	11.3	19.4	24.4	41.3
18	4.8	26.0	12.4	20.9	26.5	47.2
19	4.9	30.6	13.6	22.6	28.7	53.5
20	5.0	35.6	14.8	24.3	31.0	60.0
21	5.1	40.7	16.0	26.1	33.4	66.9
22	5.3	46.1	17.4	28.0	36.0	74.2
23	5.4	51.8	18.8	30.0	38.7	81.8
24	5.6	57.7	20.2	32.1	41.4	89.7

CONTINUED

Table 24.—Continued: CHESTNUT OAK

TREE GRADE 3
2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
10	0.0	0.0	0.0	0.0	1.1	0.4
11	.0	.0	.0	.0	1.1	.4
12	.0	.0	.0	.0	1.1	.4
13	.0	1.0	.1	.1	1.1	.4
14	.0	2.2	.3	.5	1.1	.4
15	.0	3.4	.6	.9	1.1	.4
16	.0	4.8	.9	1.4	1.1	.4
17	.0	6.3	1.2	1.8	1.1	.4
18	.0	7.8	1.5	2.3	1.1	.4
19	.0	9.4	1.8	2.9	1.1	.4
20	.0	11.2	2.1	3.5	1.1	.4
21	.0	13.0	2.5	4.0	1.1	.4
22	.0	14.9	2.9	4.7	1.1	.4
23	.0	16.9	3.3	5.3	1.1	.4
24	.0	18.9	3.7	6.0	1.1	.4
25	.0	21.1	4.1	6.7	1.1	.4
26	.0	23.4	4.6	7.5	1.1	.4

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
10	4.1	0.0	8.5	16.7	22.0	8.5
11	4.7	.0	9.1	18.2	23.2	13.4
12	5.5	.0	9.9	19.8	24.5	18.7
13	6.3	3.6	10.6	21.6	25.9	24.5
14	7.2	8.0	11.5	23.6	27.4	30.8
15	8.2	12.8	12.4	25.7	29.0	37.5
16	9.2	17.9	13.3	27.9	30.7	44.7
17	10.3	23.4	14.4	30.3	32.5	52.4
18	11.4	29.2	15.4	32.8	34.4	60.5
19	12.6	35.3	16.6	35.5	36.5	69.1
20	13.9	41.7	17.8	38.3	38.7	78.2
21	15.2	48.5	19.1	41.3	40.9	87.7
22	16.6	55.6	20.4	44.4	43.3	97.7
23	18.1	63.0	21.8	47.7	45.8	108.1
24	19.7	70.8	23.2	51.1	48.4	119.0
25	21.3	78.8	24.8	54.6	51.1	130.4
26	22.9	87.3	26.3	58.3	54.0	142.2

TREE GRADE 3
2-1/2 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
12	0.0	0.0	0.0	0.2	1.1	0.4
13	.0	1.0	.1	.6	1.1	.4
14	.0	2.2	.4	1.0	1.1	.4
15	.0	3.4	.7	1.4	1.1	.4
16	.0	4.8	1.0	1.9	1.1	.4
17	.0	6.3	1.4	2.4	1.1	.4
18	.0	7.8	1.8	2.9	1.1	.4
19	.0	9.4	2.2	3.4	1.1	.4
20	.0	11.2	2.6	4.0	1.1	.4
21	.0	13.0	3.1	4.6	1.1	.4
22	.0	14.9	3.6	5.2	1.1	.4
23	.0	16.9	4.1	5.9	1.1	.4
24	.0	18.9	4.6	6.5	1.1	.4

CONTINUED

Table 24.—Continued: CHESTNUT OAK

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
12	6.8	0.0	12.9	26.7	33.1	20.6
13	8.3	.7	13.7	29.2	34.4	28.0
14	10.0	6.2	14.5	31.9	35.8	36.0
15	11.8	12.1	15.4	34.8	37.3	44.6
16	13.8	18.5	16.4	37.9	38.9	53.7
17	15.8	25.2	17.4	41.2	40.6	63.5
18	18.0	32.4	18.5	44.8	42.4	73.8
19	20.3	39.9	19.6	48.5	44.3	84.8
20	22.8	47.9	20.8	52.4	46.3	96.3
21	25.3	56.2	22.1	56.5	48.4	108.4
22	28.0	65.0	23.4	60.8	50.6	121.1
23	30.8	74.2	24.8	65.3	53.0	134.4
24	33.7	83.8	26.3	70.0	55.4	148.3

TREE GRADE 3
3 LOGS

Dbh (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND
12	0.0	0.0	0.0	0.8	1.1	0.4
13	.0	1.0	.0	1.1	1.1	.4
14	.0	2.2	.4	1.5	1.1	.4
15	.0	3.4	.8	2.0	1.1	.4
16	.0	4.8	1.2	2.4	1.1	.4
17	.0	6.3	1.6	2.9	1.1	.4
18	.0	7.8	2.1	3.4	1.1	.4
19	.0	9.4	2.6	3.9	1.1	.4
20	.0	11.2	3.2	4.5	1.1	.4

Dbh (inches)	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
12	8.0	0.0	15.9	33.5	41.8	22.5
13	10.3	.0	16.7	36.7	42.9	31.5
14	12.8	4.4	17.5	40.2	44.2	41.2
15	15.5	11.5	18.4	43.9	45.6	51.6
16	18.4	19.0	19.4	47.9	47.1	62.7
17	21.4	27.0	20.4	52.2	48.7	74.6
18	24.6	35.5	21.5	56.7	50.3	87.1
19	28.0	44.5	22.6	61.4	52.1	100.4
20	31.6	54.0	23.8	66.4	54.0	114.4

Table 25.—Thickness distribution by lumber grade for YELLOW BIRCH, in percent

Lumber thickness (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
3/8	—	—	—	—	—	0.1	0.2
2/4	—	—	0.1	—	—	—	.1
5/8	0.1	—	—		—	—	.3
3/4	.7	0.8	2.9	2.3	1.6	2.9	3.5
4/4	44.4	43.2	56.8	64.5	69.0	71.8	66.3
5/4	40.6	35.4	32.0	27.4	25.3	19.4	10.4
6/4	5.9	11.2	7.2	4.3	2.3	.3	.2
8/4	—	—	—	.1	1.2	5.2	17.9
10/4	8.3	9.4	1.0	1.4	.6	.3	1.1

Table 26.—Thickness distribution by lumber grade for RED MAPLE, in percent

Lumber thickness (inches)	FAS	FAS1F	Selects	No. 1C	No. 2A	No. 2B	No. 3A	No. 3B
3/8	—	—	—	—	—	—	0.1	—
5/8	—	—	—	—	—	—	.1	
3/4	0.2	0.1	—	1.0	1.4	2.4	1.1	4.1
4/4	52.4	58.1	59.2	71.3	64.0	78.7	67.6	82.9
5/4	11.7	18.2	8.9	11.3	12.7	18.1	3.6	13.0
6/4	18.4	16.8	19.1	10.6	1.8	.4	.3	—
7/4	—	.5	—	—	.1	—	.1	—
8/4	17.3	6.3	12.8	5.8	10.6	.4	18.0	—
10/4	—	—	—	—	9.4	—	9.1	—

Table 27.—Thickness distribution by lumber grade for BLACK OAK, in percent

Lumber thickness (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
2/4	0.1	0.1	—	—	0.1	—	—	—
3/4	.7	—	0.5	0.8	.8	1.0	0.6	0.1
4/4	7.6	13.4	26.2	32.9	57.2	64.1	57.9	36.2
5/4	91.2	85.8	71.1	64.6	32.6	15.4	7.7	2.1
6/4	.4	.7	—	.3	.3	—	.2	—
7/4	—	—	—	.1	—	.5	—	.2
8/4	—	—	2.2	1.2	8.4	18.2	27.9	36.2
10/4	—	—	—	—	—	—	3.4	22.5
12/4	—	—	—	.1	.6	.8	2.3	2.7

Table 28.—Thickness distribution by lumber grade for BASSWOOD, in percent

Lumber thickness (inches)	FAS	Selects	No. 1C	No. 2C	No. 3C
3/4	4.0	1.3	2.7	2.6	2.4
4/4	63.0	73.5	72.2	74.3	64.6
5/4	16.4	6.0	13.9	10.7	6.8
6/4	2.6	6.4	2.2	.3	.1
8/4	14.0	11.7	8.8	7.5	5.2
9/4	—	1.1	.2	4.6	20.9

Table 29.—Thickness distribution by lumber grade for SUGAR MAPLE, in percent

Lumber thickness (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
3/4	0.1	0.3	0.7	0.3	0.7	0.6	1.8
4/4	10.2	11.5	40.6	22.5	36.6	49.2	53.7
5/4	73.7	60.7	52.9	60.2	48.1	36.9	13.7
6/4	.5	—	—	.3	.4	.4	.3
8/4	15.5	27.5	5.8	16.7	14.2	12.9	29.5
10/4	—	—	—	—	—	—	1.0

Table 30.—Thickness distribution by lumber grade for BLACK CHERRY, in percent

Lumber thickness (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
3/4	0.3	0.2	0.2	0.2	0.8	0.9
4/4	49.7	58.5	79.7	90.3	70.7	85.0
5/4	1.9	3.1	2.0	3.3	.6	.4
6/4	20.9	17.5	11.5	2.8	1.5	.4
8/4	27.2	20.7	6.6	3.3	24.2	12.3
12/4	—	—	—	.1	2.2	1.0

Table 31.—Thickness distribution by lumber grade for PAPER BIRCH, in percent

Lumber thickness (inches)	FAS	Selects	No. 1C	No. 2C	No. 3A	No. 3B
2/4	—	—	0.1	—	—	0.1
5/8	—	—	—	0.8	0.1	—
3/4	0.4	1.0	1.1	1.9	3.3	4.5
4/4	99.6	98.8	98.8	97.2	96.4	95.3
5/4	—	.2	—	.1	.2	.1

Table 32.—Thickness distribution by lumber grade for WHITE OAK, in percent

Lumber thickness (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	SW	No. 3A	No. 3B
3/4	0.7	1.0	0.6	1.3	1.9	1.7	3.1	2.7
4/4	25.1	27.2	45.5	45.8	71.6	65.8	78.9	71.4
5/4	45.7	38.1	28.3	38.2	20.5	14.0	4.7	1.1
6/4	28.5	33.7	25.6	14.5	4.1	3.1	.4	.1
8/4	—	—	—	.2	1.9	15.4	12.9	24.7

Table 33.—Thickness distribution by lumber grade for YELLOW-POPLAR, in percent

Lumber thickness (inches)	FAS	Selects	Saps	No. 1C	No. 2A	No. 2B	No. 3C
2/4	—	—	—	—	0.1	0.1	0.1
5/8	—	0.7	0.1	0.1	.1	—	—
3/4	4.9	1.0	1.7	1.6	1.9	2.6	2.6
4/4	81.6	87.5	67.2	87.5	86.8	84.4	81.9
5/4	.5	3.3	2.8	.2	1.0	2.2	2.5
6/4	11.8	6.2	19.4	9.7	4.7	.4	3.4
8/4	1.2	1.3	8.9	.9	5.4	10.3	9.5

Table 34.—Thickness distribution by lumber grade for NORTHERN RED OAK, in percent

Lumber thickness (inches)	FAS	FAS1F	Selects	No. 1C	No. 2C	No. 3A	No. 3B
5/8	0.1	—	—	0.1	0.1	0.2	0.2
3/4	.3	0.5	0.2	.8	1.2	2.0	2.2
4/4	26.2	37.6	53.2	57.8	86.8	93.6	92.3
5/4	61.9	56.3	46.1	39.7	11.4	3.6	2.6
6/4	11.5	5.6	.5	1.6	.2	.1	.4
8/4	—	—	—	—	.3	.5	2.3

Table 35.—Thickness distribution by lumber grade for CHESTNUT OAK, in percent

Lumber thickness (inches)	FAS	FAS WHND	FAS1F	FAS1F WHND	Selects	Selects WHND	No. 1C	No. 1C WHND	No. 2C	SW	No. 3A	No. 3B
1/2	—	—	0.1	—	—	—	0.1	—	0.1	0.1	0.1	—
5/8	—	—	—	—	—	—	.2	0.2	.1	—	.1	
3/4	0.9	0.3	.1	0.2	0.6	—	.5	.5	1.4	1.4	2.9	2.4
4/4	31.5	25.2	28.7	24.6	60.0	76.2	51.8	56.2	90.0	78.2	93.6	94.8
5/5	25.0	18.3	20.4	22.2	28.3	7.2	18.8	21.0	5.6	13.1	1.7	1.9
6/4	42.6	56.2	50.7	53.0	11.1	16.6	28.6	22.1	2.8	7.2	1.6	.9

Table 36.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for YELLOW BIRCH

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
TREE GRADE 1 (Basis: 63 Trees)			
FAS	74.3	43.2	0.73
FAS1F	35.0	20.6	.56
Selects	9.1	9.2	.20
No. 1C	97.9	47.6	.86
No. 2C	71.0	31.9	.71
No. 3A	41.2	19.3	.76
No. 3B	35.1	21.6	.45
TREE GRADE 2 (Basis: 69 Trees)			
FAS	19.6	21.8	0.56
FAS1F	16.3	13.7	.51
Selects	6.1	7.7	.08
No. 1C	53.6	27.6	.62
No. 2C	46.8	18.5	.73
No. 3A	34.2	17.9	.42
No. 3B	31.4	17.7	.64
TREE GRADE 3 (Basis: 61 Trees)			
FAS	1.2	2.9	0.34
FAS1F	4.6	6.6	.54
Selects	1.9	4.1	.07
No. 1C	27.9	14.0	.86
No. 2C	37.7	16.0	.84
No. 3A	27.7	14.2	.70
No. 3B	27.7	13.3	.48

Table 37.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for RED MAPLE

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
	TREE GRADE 1 (Basis: 66 Trees)		
FAS	63.7	43.3	0.68
FAS1F	53.0	24.6	.55
Selects	17.7	11.7	.55
No. 1C	66.7	27.5	.73
No. 2A	65.5	32.3	.47
No. 2B	48.8	23.2	.21
No. 3A	20.3	14.4	.33
No. 3B	12.2	9.5	.56
	TREE GRADE 2 (Basis: 79 Trees)		
FAS	21.9	22.3	0.66
FAS1F	26.6	16.7	.68
Selects	10.9	9.6	.34
No. 1C	38.4	19.5	.71
No. 2A	57.3	30.0	.42
No. 2B	49.1	34.3	.16
No. 3A	16.1	16.2	.27
No. 3B	8.7	11.9	.56
	TREE GRADE 3 (Basis: 118 Trees)		
FAS	3.8	7.3	0.36
FAS1F	8.1	10.3	.57
Selects	5.8	5.7	.43
No. 1C	23.6	14.8	.75
No. 2A	36.4	24.0	.62
No. 2B	49.4	28.6	.46
No. 3A	13.5	13.5	.38
No. 3B	7.3	13.2	.30

Table 38.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for BLACK OAK

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
TREE GRADE 1 (Basis: 71 Trees)			
FAS	55.0	35.5	0.80
FAS1F	53.5	30.7	.75
Selects	11.8	14.0	.43
No. 1C	185.1	72.6	.81
No. 2C	111.7	48.1	.62
SW	20.5	25.1	.22
No. 3A	83.7	31.6	.49
No. 3B	59.9	45.3	.48
TREE GRADE 2 (Basis: 62 Trees)			
FAS	25.1	24.1	0.66
FAS1F	29.9	16.7	.80
Selects	4.9	6.7	.38
No. 1C	108.5	32.9	.93
No. 2C	83.8	31.9	.84
SW	9.8	11.0	.44
No. 3A	60.0	28.6	.61
No. 3B	37.0	38.5	.31
TREE GRADE 3 (Basis: 48 Trees)			
FAS	7.6	11.8	0.59
FAS1F	13.1	13.7	.77
Selects	3.0	5.1	.57
No. 1C	57.2	27.9	.92
No. 2C	53.1	23.0	.85
SW	12.5	12.6	.37
No. 3A	42.2	26.5	.61
No. 3B	47.3	39.1	.57

Table 39.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for BASSWOOD

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
	TREE GRADE 1 (Basis: 51 Trees)		
FAS	53.7	30.4	0.85
Selects	59.0	25.9	.60
No. 1C	74.8	32.4	.59
No. 2C	107.8	40.4	.61
No. 3C	33.2	25.2	.59
	TREE GRADE 2 (Basis: 44 Trees)		
FAS	13.7	10.2	0.82
Selects	35.5	20.5	.79
No. 1C	52.0	23.7	.77
No. 2C	83.6	28.0	.69
No. 3C	29.4	18.5	.79
	TREE GRADE 3 (Basis: 53 Trees)		
FAS	3.6	6.0	0.49
Selects	10.2	10.0	.67
No. 1C	27.8	22.4	.60
No. 2C	72.4	22.9	.85
NO. 3C	23.1	15.1	.63

Table 40.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for SUGAR MAPLE

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
	TREE GRADE 1 (Basis: 58 Trees)		
FAS	49.4	45.7	0.62
FAS1F	49.9	27.7	.54
Selects	8.7	8.4[a]	(a)
No. 1C	111.3	52.1	.79
No. 2C	82.9	28.0	.75
No. 3A	43.3	24.9	.53
No. 3B	55.9	27.6	.56
	TREE GRADE 2 (Basis: 61 Trees)		
FAS	20.0	21.6	0.51
FAS1F	35.2	24.1	.65
Selects	7.6	7.3[a]	(a)
No. 1C	89.5	29.9	.89
No. 2C	69.5	25.2	.79
No. 3A	36.7	17.8	.64
No. 3B	37.9	23.1	.57
	TREE GRADE 3 (Basis: 60 Trees)		
FAS	4.4	9.3	0.44
FAS1F	9.7	13.2	.52
Selects	5.3	6.1	.43
No. 1C	46.0	35.8	.73
No. 2C	52.6	25.3	.84
No. 3A	40.7	27.1	.65
No. 3B	48.3	33.5	.51

[a] For this lumber grade, the mean lumber volume was used instead of a regression equation. Therefore, standard deviation has been substituted for standard error, and the multiple correlation coefficient has been omitted.

Table 41.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for BLACK CHERRY

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
TREE GRADE 1 (Basis: 78 Trees)			
FAS	75.3	26.5	0.79
Selects	55.0	26.7	.65
No. 1C	70.6	28.0	.79
No. 2C	60.8	22.9	.72
No. 3A	38.2	19.9	.58
No. 3B	12.7	13.9	.39
TREE GRADE 2 (Basis: 49 Trees)			
FAS	22.3	16.4	0.65
Selects	37.4	16.7	.60
No. 1C	58.1	18.3	.90
No. 2C	58.0	16.4	.79
No. 3A	33.8	19.4	.42
No. 3B	8.1	9.6	.31
TREE GRADE 3 (Basis: 71 Trees)			
FAS	6.3	9.0	0.74
Selects	15.5	15.6	.73
No. 1C	33.6	19.5	.87
No. 2C	40.0	18.3	.77
No. 3A	37.4	17.2	.70
No. 3B	9.8	10.9	.29

Table 42.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for PAPER BIRCH

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
	TREE GRADE 1 (Basis: 36 Trees)		
FAS	28.2	15.2	0.31
Selects	38.3	17.2	.43
No. 1C	43.6	17.8	.63
No. 2C	46.8	20.1	.40
No. 3A	36.4	12.9	.62
No. 3B	24.3	15.1	.48
	TREE GRADE 2 (Basis: 61 Trees)		
FAS	8.4	7.9	0.61
Selects	20.7	11.8	.54
No. 1C	27.0	11.1	.75
No. 2C	35.6	13.0	.57
No. 3A	34.5	12.7	.58
No. 3B	20.5	12.8	.39
	TREE GRADE 3 (Basis: 61 Trees)		
FAS	2.4	5.9	0.40
Selects	7.9	6.4	.45
No. 1C	19.3	11.3	.74
No. 2C	28.8	13.9	.74
No. 3A	27.8	12.9	.59
No. 3B	22.0	14.0	.44

Table 43.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for WHITE OAK

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
TREE GRADE 1 (Basis: 108 Trees)			
FAS	34.5	32.5	0.61
FAS1F	29.4	23.8	.61
Selects	11.5	12.2	.47
No. 1C	93.9	45.6	.90
No. 2C	112.8	47.2	.81
SW	24.3	42.5	.50
No. 3A	61.6	32.5	.54
No. 3B	39.3	31.6	.35
TREE GRADE 2 (Basis: 121 Trees)			
FAS	8.2	13.2	0.41
FAS1F	12.0	15.2	.43
Selects	3.9	7.4[a]	(a)
No. 1C	51.1	36.3	.81
No. 2C	59.6	32.3	.83
SW	22.3	33.5	.45
No. 3A	40.8	21.4	.68
No. 3B	33.5	28.8	.29
TREE GRADE 3 (Basis: 75 Trees)			
FAS	2.2	7.5	0.43
FAS1F	3.0	7.1	.48
Selects	1.4	3.3	.20
No. 1C	23.4	28.5	.81
No. 2C	44.8	33.2	.84
SW	17.1	32.0	.56
No. 3A	43.1	24.1	.72
No. 3B	45.8	32.4	.49

[a] For this lumber grade, the mean lumber volume was used instead of a regression equation. Therefore, standard deviation has been substituted for standard error, and the multiple correlation coefficient has been omitted.

Table 44.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for YELLOW-POPLAR

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
	TREE GRADE 1 (Basis: 63 Trees)		
FAS	3.5	10.3	0.43
Selects	10.8	15.3	.52
Saps	17.9	17.3	.43
No. 1C	164.7	57.8	.85
No. 2A	169.0	62.2	.62
No. 2B	81.1	51.7	.71
No. 3C	4.2	7.4	.19
	TREE GRADE 2 (Basis: 50 Trees)		
FAS	1.0	4.5	0.20
Selects	3.5	8.6	.49
Saps	9.2	13.2	.27
No. 1C	89.4	50.1	.84
No. 2A	124.9	61.6	.77
No. 2B	67.6	45.7	.63
No. 3C	5.3	7.0	.51
	TREE GRADE 3 (Basis: 46 Trees)		
FAS	0.0	0.0	(a)
Selects	2.3	8.5	0.25
Saps	1.9	4.7	.24
No. 1C	42.6	45.2	.70
No. 2A	76.5	47.4	.77
No. 2B	84.2	56.6	.72
No. 3C	8.1	14.8	.08

[a] For this lumber grade, the mean lumber volume was 0.0. Therefore, the multiple correlation coefficient has been omitted.

Table 45.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for NORTHERN RED OAK

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
	TREE GRADE 1 (Basis: 95 Trees)		
FAS	151.4	65.7	0.80
FAS1F	87.0	40.3	.74
Selects	17.1	19.2	.39
No. 1C	221.2	64.6	.86
No. 2C	134.6	36.2	.75
No. 3A	52.3	26.6	.42
No. 3B	24.0	31.2	.33
	TREE GRADE 2 (Basis: 58 Trees)		
FAS	51.4	48.0	0.62
FAS1F	38.7	(a)	(a)
Selects	3.7	5.8[b]	(b)
No. 1C	164.2	(a)	(a)
No. 2C	111.4	33.1	.86
No. 3A	53.6	28.5	.52
No. 3B	17.7	17.4	.50
	TREE GRADE 3 (Basic: 66 Trees)		
FAS	5.3	9.5	0.51
FAS1F	8.9	14.4	.50
Selects	2.0	3.9[b]	(b)
No. 1C	42.2	28.3	.80
No. 2C	56.1	24.0	.87
No. 3A	50.2	23.1	.73
No. 3B	41.0	28.6	.63

[a] Meaningful standard errors and multiple correlation coefficients for this lumber grade were not obtained.

[b] For this lumber grade, the mean lumber volume was used instead of a regression equation. Therefore, standard deviation has been substituted for standard error and the multiple correlation coefficient has been omitted.

Table 46.—Mean lumber volumes, standard errors of the residuals, and correlation coefficients for CHESTNUT OAK

Lumber grade	Mean lumber volume (board feet)	Standard error of the residual (board feet)	Multiple correlation coefficient
TREE GRADE 1 (Basis: 82 Trees)			
FAS	20.7	(a)	(a)
FAS-WHND	49.0	49.2	0.57
FAS1F	20.6	22.5	.43
FAS1F-WHND	11.6	17.5	.35
Selects	3.2	4.4[b]	(b)
Selects-WHND	1.3	3.3[b]	(b)
No. 1C	43.0	(a)	(a)
No. 1C-WHND	66.5	34.3	.81
No. 2C	35.5	25.8	.38
SW	50.7	33.9	.56
No. 3A	46.1	29.8	.48
No. 3B	64.9	50.5	.59
TREE GRADE 1 (Basic: 99 Trees)			
FAS	3.3	7.7	0.20
FAS-WHND	20.0	23.3	.71
FAS1F	8.9	16.5	.49
FAS1F-WHND	6.3	8.8	.58
Selects	2.9	3.8	.43
Selects-WHND	1.1	4.7	.27
No. 1C	18.9	18.2	.23
No. 1C-WHND	40.6	27.5	.80
No. 2C	22.7	22.0	.23
SW	33.9	22.8	.51
No. 3A	37.7	21.7	.35
No. 3B	50.3	36.6	.65
TREE GRADE 3 (Basis: 75 Trees)			
FAS	0.0	0.0[b]	(b)
FAS-WHND	5.5	9.3	0.50
FAS1F	1.0	4.1	.26
FAS1F-WHND	1.5	5.2	.34
Selects	1.1	3.4[b]	(b)
Selects-WHND	.4	1.6[b]	(b)
No. 1C	9.2	10.9	.52
No. 1C-WHND	20.5	18.2	.74
No. 2C	13.4	13.4	.34
SW	28.8	25.8	.53
No. 3A	30.4	21.0	.45
No. 3B	47.3	25.9	.76

[a] Meaningful standard errors and multiple correlation coefficients for this lumber grade were not obtained.

[b] For this lumber grade, the mean lumber volume was used instead of a regression equation. Therefore, standard deviation has been substituted for standard error and the multiple correlation coefficient has been omitted.

Table 47.—Means and standard deviations for dbh and merchantable height, by species and tree grade

Species	Tree grade	Dbh (inches)		Merchantable height (feet)	
		Mean	Standard deviation	Mean	Standard deviation
Yellow birch	1	21.4	4.6	37.3	7.9
	2	18.4	3.7	32.6	7.5
	3	15.0	3.5	27.7	7.6
Red maple	1	19.5	2.5	42.2	9.1
	2	16.4	2.6	38.0	7.7
	3	14.4	2.8	32.3	8.1
Black oak	1	23.9	4.5	47.4	9.9
	2	20.2	4.7	37.9	9.2
	3	15.5	5.1	28.9	9.9
Basswood	1	18.5	3.0	46.9	9.5
	2	16.4	2.9	35.6	10.0
	3	14.7	3.1	32.2	10.1
Sugar maple	1	21.7	4.0	38.6	9.0
	2	20.1	4.2	34.6	8.3
	3	17.6	5.0	29.6	8.5
Black cherry	1	19.2	2.7	38.8	7.9
	2	17.1	2.8	36.0	7.1
	3	15.4	3.6	30.5	7.9
Paper birch	1	18.0	1.6	35.7	6.2
	2	15.6	2.2	34.5	7.1
	3	14.0	2.6	29.4	7.6
White oak	1	21.8	4.1	42.1	11.4
	2	18.9	3.6	34.2	10.7
	3	17.4	4.9	33.6	10.8
Yellow-poplar	1	20.4	3.5	50.3	10.9
	2	18.6	3.9	49.1	11.7
	3	17.1	3.1	45.1	10.6
Northern red oak	1	25.4	4.4	46.0	10.7
	2	22.0	5.3	36.2	8.8
	3	16.8	4.8	30.8	9.4
Chestnut oak	1	21.7	3.8	39.8	9.7
	2	18.7	4.3	34.4	7.6
	3	16.1	3.4	30.9	7.2

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Hanks, Leland F.
1976. **HARDWOOD TREE GRADES FOR FACTORY LUMBER.**
Northeast. For. Exp. Stn., Upper Darby, Pa.
81 p., illus. (USDA For. Serv. Res. Pap. NE-333)

The Forest Service hardwood tree grades for factory lumber are described, and lumber grade yields for 11 species are presented. The yields, expressed in board feet, are based on equations in which dbh^2 and merchantable height were used as independent variables. Actual board-foot volumes by lumber grade served as dependent variables. Species included are yellow and paper birch, red and sugar maple, yellow-poplar, black cherry, basswood, and northern red, black, white, and chestnut oak.

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Manufacturing Interior Furniture Parts: A New Look at an Old Problem

by Edwin L. Lucas
and Philip A. Araman

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F. BRYAN CLARK, STATION DIRECTOR

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Manufacturing Interior Furniture Parts: A New Look at an Old Problem

ABSTRACT

The yields of interior furniture parts from four manufacturing sequences were compared. In three of the sequences, gang-ripping was the first step; in the fourth, the lumber was crosscut first. Though the grade of lumber used affects the percentage yield of parts, the manufacturing sequence used does not—but it will affect the cost per part. The selection of the best method must be based on factors other than parts yield.

Keywords: Lumber yield, furniture manufacture, wood utilization.

FEW FURNITURE MANUFACTURERS have rough mill lines set up exclusively for the production of interior furniture parts. But now some manufacturers are finding that the demand for interior parts warrants the establishment of a specialized interior-parts line or mill to supply one or more assembly plants.

An interior part is a structural part of a furniture frame that is hidden from view. Its primary function is strength. It can contain any sound defect that (1) does not materially weaken the strength of the piece and (2) does not occur in the outer inch of either end where machining for joining is necessary. For a given line of furniture, almost all the interior parts have the same width and thickness; they vary only in length.

The allowance of sound defects and the constant width and thickness of parts suggest that gang-ripping of boards before crosscutting may have advantages over the conventional technique of crosscutting first. To test this, we compared four manufacturing sequences and three grades of 4/4 yellow-poplar lumber. The basis for comparison was the yield of usable parts recovered from the lumber.

Though the results showed that the grade of lumber does affect the percentage yield of parts, the manufacturing sequence used had no influence on yield. However, the manufacturing sequence used will affect the final cost of the part. Therefore the selection of the best method must be based on factors other than lumber yield.

THE STUDY

The study was conducted in two phases. In phase I, the percentage yield of parts from three rip-first manufacturing sequences was tested, using 1 Common (1C) and 2A Common (2AC) 4/4 kiln-dried yellow-poplar lumber. Phase II was conducted to check the assumption that gang-ripping would increase the yield of parts when compared to a crosscut-first production process. In phase II, the crosscut-first process was compared with what we judged to be the two best gang-rip-first sequences of phase I. Two B Common (2BC) 4/4 kiln-dried yellow-poplar lumber was used in phase II.

Cutting Order

The cutting order used (table 1) was provided by a furniture manufacturer. It is typical of the part sizes and frequency distributions the manufacturer would require in a centralized interior-parts plant.

Table 1.—Cutting order distribution for 1-11/16-inch-wide 4/4 yellow-poplar interior furniture parts

Cutting No.	Length of cutting	Frequency distribution
	Inches	*Percent*
1	73	5
2	62	7
3	56	2
4	37	6
5	36	8
6	30	3
7	24	17
8	22	3
9	16	14
10	15	32
11	13	3

This cutting order contained 11 lengths, ranging from 13 to 73 inches. The width of all parts was 1-11/16 inches. The frequency distribution in the cutting order represents percentages of the total number of parts required; that is, for every 100 parts produced, 5 should be 73 inches long, 7 should be 62 inches long, etc. The actual number of parts to be cut to meet these requirements depends upon the parts yield of a given amount of a given grade of lumber.

Design and Test of Manufacturing Sequences

Four manufacturing sequences were studied (fig. 1). For sequences 1, 2, and 3, the first operation was gang-ripping full-length lumber into strips 1-11/16 inches wide. For sequence 4, all lumber was first crosscut to lengths dictated by the cutting bill and then gang-ripped into 1-11/16-inch strips.

In phase I, we simulated the step-by-step procedures for sequences 1, 2, and 3 for gang-ripping two 500-board-foot samples of yellow-poplar to width. The entire 1,000 board feet of strips were marked for interior parts according to the steps shown in sequence 2. Then the 500-board-foot samples were physically crosscut into parts according to the steps in sequences 1 and 3.

In phase II, approximately 500 board feet of yellow-poplar lumber were physically processed according to the steps in sequences 2, 3, and 4.

DETAILS OF THE SEQUENCES

Sequence 1

The strips from the gang-ripping operation were crosscut in a conventional manner to specified lengths, using a crosscut saw equipped with a back-gage. After crosscutting, the parts were tallied.

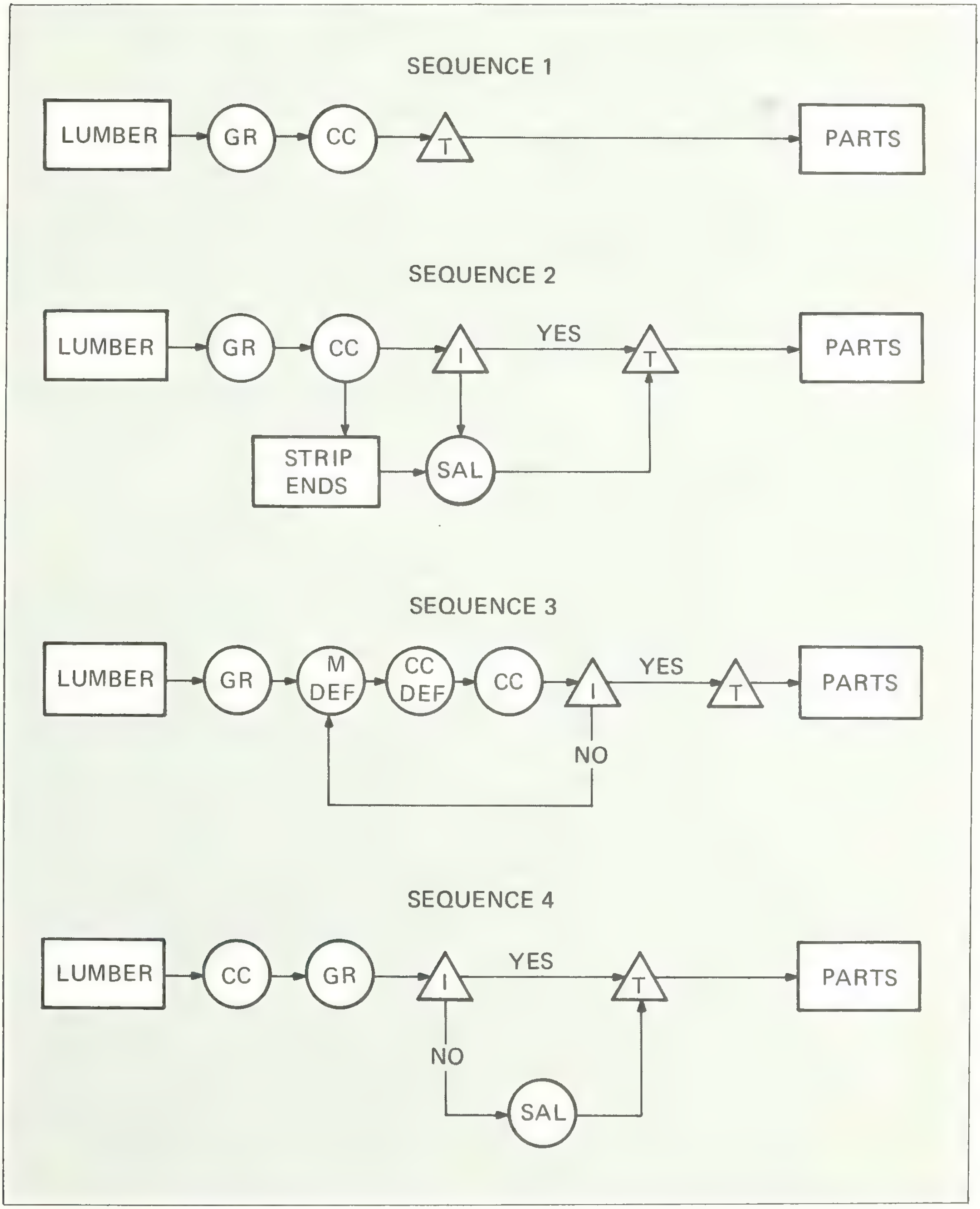
It is conventionally accepted that a crosscut saw operator cannot efficiently remember more than five different cutting lengths at one time. Therefore, we established a cutting bill of five lengths (one primary and four secondary). Initially, this cutting bill included cuttings 1, 3, 5, 7, and 9 from the original cutting order (table 1). The primary length was the longest of the five. When the required numbers of a given length were cut, the next longest cuttings in the original cutting order were made. This procedure was repeated until the required numbers of the 11 lengths in the original cutting order were sawed.

Sequence 2

Sequence 2, recommended by a manufacturer of interior parts, was an effort to introduce more automation into the process. As with sequence 1, a cutting bill (one primary and four secondary cuttings) was used. But an important difference occurred at the crosscutting station. Here strips were crosscut to the primary length, regardless of defect location, with a conveyorized crosscut saw (simulated in this study). Such a saw would automatically cut the strips to the primary length

Figure 1.—Flow diagrams of four manufacturing sequences for producing interior furniture parts.

GR = Gang-ripping station, where lumber is ripped into 1-11/16-inch strips.
CC = Crosscutting station, where lumber or strips are cut to specified lengths.
M DEF = Defect-marking station.
CC DEF = Mark-sensing crosscutting station, where defects are cut out.
SAL = Salvage station, where rejected pieces are cut to shorter usable lengths.
I = Inspection station.
T = Tally station, where parts produced are counted.



as they passed continuously, end-to-end, along a conveyor.

Since the conveyorized crosscut saw automatically cut the strips to the length of the primary cutting with no consideration for defect location, it was necessary to inspect all cuttings coming from this saw. All rejected primary cuttings were sent to a salvage crosscutting station, where they were cut back to one of the four secondary lengths. Strip ends from the conveyorized crosscutting operation were also converted into one of four secondary cuttings at the salvage saw.

The five cutting lengths used in the initial cutting bill for sequence 1 were also used at the start of this test. The primary length (cutting No. 1) was set up at the simulated crosscut saw, and the four secondary cuttings (Nos. 3, 5, 7, and 9) were used at the salvage station. As the bill for a cutting was filled, the next longest cutting in the cutting order was used.

Sequence 3

Sequence 3, designed to minimize operator decisions, was highly automated. After gang-ripping, full-length strips were sent to a marking station, where marks were made on either side of strength-reducing defects. No consideration was given at this point to whether allowable defects might occur at the ends of soon-to-be-cut-to-length parts, which would cause these parts to be rejected. The marked strips were sent to an automatic mark-sensing cutoff saw, where the defects were cut out and random-length sound strips were produced.

The sound strips were then automatically (simulated) crosscut into parts by first taking the longest cutting possible. For our cutting bill, a sound strip 92 inches long would first produce a 73-inch part. The remaining 19-inch strip would yield a 16-inch part and 3 inches of waste (less kerf). Likewise, a 72-inch strip would be cut into a 64-inch part, and 8 inches of waste would remain. Note: the 72-inch part is not cut into two 36-inch long parts.

Since the longest possible cutting is always cut first in method 3, a cutting bill is no longer necessary. All lengths in the original cutting order can be set up at the crosscutting station. As the required number of parts of any length is satisfied, that length is simply removed from the setup.

All parts coming from the cut-to-length station were inspected, and any parts having defects in their ends were rejected and returned to the defect-marking station for further processing.

Sequence 4

Sequence 4 represents a conventional manufacturing method in which the lumber is crosscut first. As in sequences 1 and 2, a cutting bill of five lengths (1 primary and 4 secondary) was required at the crosscutting station. The cut-to-length short boards were conveyed to a ripsaw, where they were gang-ripped into parts 1-11/16 inches wide. The parts were inspected as they came from the ripsaw. Rejected parts were sent to a salvage station where, if possible, they were cut back to one of the four secondary lengths.

As the number of cuttings for each length was satisfied, the next longest cutting was added to the cutting order.

RESULTS

The first phase of the study was to determine if there were any differences in yield among the three gang-rip-first manufacturing sequences. The results show that, when 1C or 2AC yellow-poplar lumber is used, the manufacturing sequence has no influence on the yield of parts recovered (table 2). The average yield of interior parts was 77 percent from 1C lumber and 72 percent from 2AC lumber.

The second phase of the study was to compare the yield recovery from a crosscut-first sequence with what we judged to be the two best gang-rip-first sequences of phase I. Since there were no real differences in yield among the gang-rip-first sequences, we chose sequences 2 and 3 for the comparison because they could be more easily automated. The results show that there is no difference in the yield of parts recovered between the crosscut-first sequence and the two gang-rip-first sequences (table 3). The average yield of parts from 2BC lumber was 64 percent.

We evaluated the effect of lumber grade on parts yield by using the results from sequences

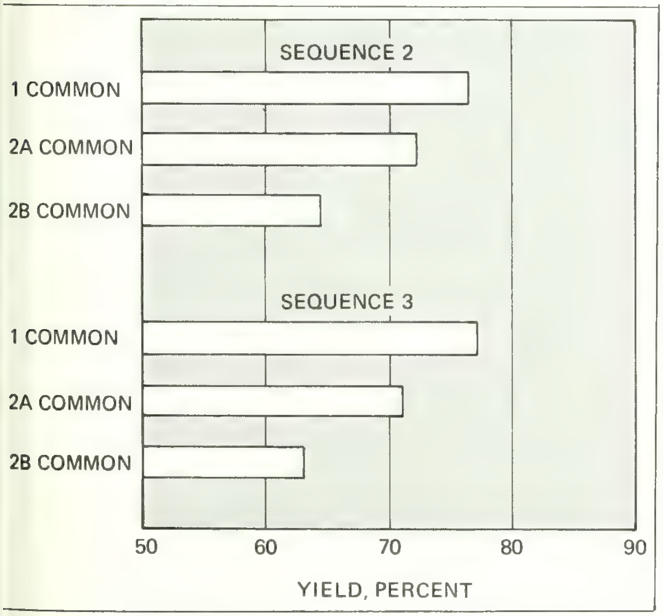
Table 2.—The yield of interior parts from 4/4 yellow-poplar lumber, by manufacturing sequence and lumber grade: phase I

Manufacturing sequence	Lumber grade	Lumber volume	Parts yield	
		Bd. ft.	*Bd. ft.*	*Percent*
1	1C	500	385	77
2	1C	1000	758	76
3	1C	500	383	77
1	2AC	500	366	73
2	2AC	1000	722	72
3	2AC	500	354	71

Table 3.—The yield of interior parts from 4/4 2BC yellow-poplar lumber, by manufacturing sequence: phase II

Manufacturing sequence	Lumber volume	Parts yield	
	Bd. ft.	*Bd. ft.*	*Percent*
2	487	314	64
3	487	307	63
4	485	317	65

Figure 2.—The effect of lumber grade on the yield of interior furniture parts in manufacturing sequences 2 and 3.



2 and 3 (fig. 2). The results show that there is no practical difference in yield between 1C and 2AC for either manufacturing sequence. However, there was a major difference in yield between 1C and 2BC for both manufacturing sequences.

DISCUSSION

Within a given grade of lumber, the yield of interior parts is not affected by any of the sawing methods tested. However, this does not mean that there is no best way to process any one grade of lumber into interior parts. Though the yield of parts is not affected, the cost per part may be. Therefore the selection of the best method must be based on criteria other than parts yield.

Consider the effect of lumber grade on parts cost. There is no practical difference in parts yield between 1C and 2AC lumber. But there is a real difference in price between 1C and 2AC. In 1974, 2AC averaged 34 percent less in price than 1C. So, 2AC is the least-cost lumber choice for producing interior parts.

In comparing 2AC and 2BC, the choice is not as clear-cut as it might first appear. Though the yield of parts from 2AC is 8 percent greater than the yield from 2BC, 2AC costs 43 percent more than 2BC in 1974. On the other hand, the appearance of the 2AC parts was far better than that of the 2BC parts, the difference in appearance being due primarily to the greater number and size of defects in the parts produced from 2BC. Even though appearance is not a grading factor for interior parts, manufacturers might want to consider how the finished product would look to a customer who pulls out drawers or otherwise looks into product construction.

Reductions in the total cost of manufacturing can often be achieved through automation. By increasing the number of steps done automatically, we reduce the chances for operator error. In sequences 1, 2, and 4, cutting bills are used, and the chance of error occurs between the tally station and the worker carrying the cutting bill in his head. Also, problems can occur when the cutting bill is changed, particularly if this is done frequently.

The two most highly automated sequences

are 2 (conveyorized crosscutting) and 3 (automatic cutting to length). The technology required for these sequences is available. A drawback to sequence 2 is the high percentage of primary parts rejected. Fifteen percent of the primary parts were rejected when cutting 1C lumber, and 21 percent and 41 percent of the primary parts were rejected when cutting 2AC and 2BC lumber. Though this did not reflect adversely on the total yield, it does require extra handling of the rejected parts to and from the salvage station.

The marking and defect-removal operations in sequence 3 overcome the problem of rejecting large numbers of cut-to-length parts. Though it is possible that prohibitive defects might occur in the ends of the cut-to-length parts, this did not occur in our tests. Therefore we believe that the number of rejected parts will be small.

Sequence 3 has a further advantage in that operator involvement is kept to a minimum. The marking of prohibitive defects is the only operator decision necessary. As cutting to length is done automatically, and all lengths in the cutting bill are considered, there is no overrun or shortage in any length.

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Araman, Philip A., and Edwin L. Lucas.
1975. AN AUTOMATED ROUGH MILL FOR THE PRODUCTION OF INTERIOR FURNITURE PARTS. USDA For. Serv. Res. Pap. NE-335. 5 p., illus.

Lucas, Edwin L., and Philip A. Araman.
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The yields of interior furniture parts from four manufacturing sequences were compared. In three of the sequences, gang-ripping was the first step; in the fourth, the lumber was crosscut first. Though the grade of lumber used affects the percentage yield of parts, the manufacturing sequence used does not—but it will affect the cost per part. The selection of the best method must be based on factors other than parts yield.

Keywords: Yield lumber, furniture manufacturing, wood utilization.

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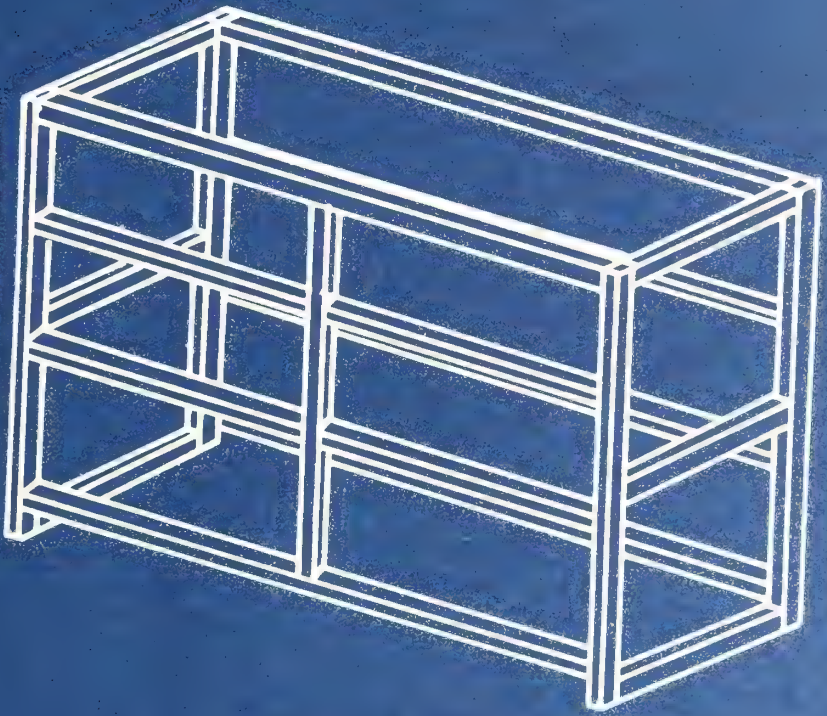
An Automated Rough Mill for the Production of Interior Furniture Parts



by Philip A. Araman
and Edwin L. Lucas

USDA FOREST SERVICE RESEARCH PAPER NE-335
1975
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An Automated Rough Mill for the Production of Interior Furniture Parts

ABSTRACT

An automated rough mill layout has been designed for manufacturing interior furniture parts. Designed to reduce human decisions and mistakes that can be costly when converting lumber into parts, the mill is based on a manufacturing sequence in which lumber is first gangsaw-ripped into standard-width strips before being crosscut to remove defects and cut to specific lengths. It is also expected to reduce manpower requirements, provide coordinated materials handling, provide better production control, and ensure consistently good yields. Standardization to one or a few widths permits maximum efficiency and yield. A major furniture manufacturer has built a mill based on the design.

Keywords: furniture manufacturing, automatic control

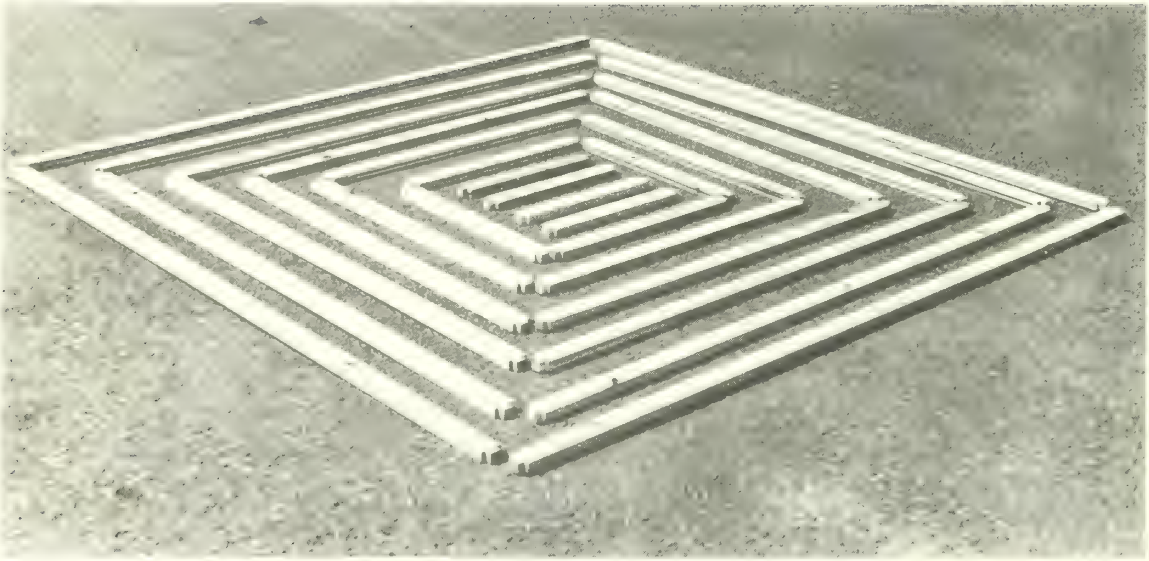


Figure 1.—Interior furniture parts. All of a standard thickness and width, but of different lengths, these parts have been tenoned and grooved and are ready for use.

A NEW KIND OF ROUGH MILL

AT PRESENT, INTERIOR furniture parts are generally produced in conventional rough mills where the lumber is first *crosscut* into the desired *lengths.* A major disadvantage of this method is that conventional rough mills are set up to produce many different sizes of exterior parts rather than the more standardized interior parts. Excessive manpower is needed in a conventional rough mill to produce interior parts, and undercutting and overcutting the number of parts required is always a problem. Furthermore, all cutting decisions are made by human operators, and wrong decisions reduce yield and are costly.

Interior furniture parts (fig. 1) are usually required in a few standard sizes. Hidden from view, these parts are primarily structural. They can contain defects that do not greatly reduce strength, except on the ends, where machining is required.

Our studies of sawing methods *(Lucas and Araman 1975)* led us to design an automated mill for producing these parts by first *ripping* the lumber into the desired *widths.* We believed that, through automation, we could reduce manpower requirements and provide coordinated materials handling and production control.

Another benefit we looked for was a reduction in the number of decisions that are required of workers in a conventional rough mill. This would minimize the mistakes that can be so costly in converting lumber into furniture parts.

A major furniture manufacturer has built a mill based on our research and development. The ideas presented here can be used for any product of standard width such as strip flooring.

ROUGH MILL LAYOUT

Our rough mill layout is based on a manufacturing sequence in which lumber is first gangsaw-ripped into strips of standard width and then is crosscut to remove defects and produce interior furniture parts of several desired lengths.

A computer simulation technique was used in designing the rough mill. With this technique, production problems and bottlenecks can be found and eliminated before a mill is actually built.

Our rough mill was designed to produce 4,000 net board feet of interior furniture parts per 8-hour shift from No. 2A Common yellow-poplar lumber. Simulated output ranged from 3,500 board feet from No. 2B Common lumber to 4,400 board feet from No. 1 Common lumber.

The mill was designed to perform four major actions in the manufacturing sequence (fig. 2):

1. The kiln-dried lumber is planed to a uniform thickness.
2. The lumber is gangsaw-ripped into strips of standard width.
3. Objectionable defects are removed from the strips by crosscutting.
4. The strips, now defect-free, are crosscut into several required lengths; the longest obtainable length is cut first.

In designing the mill, we used information provided by several equipment manufacturers. The equipment required is now available or could be devised from available components.

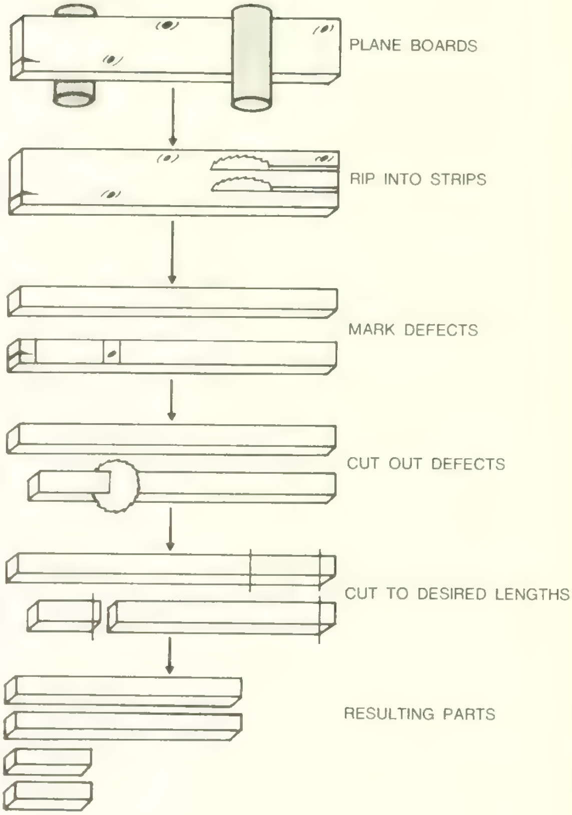
The mill requires a work crew of only three. Let's call them Al, Babe, and Charlie (positions A, B, and C in figure 3).

ROUGH MILL OPERATION

The following sequence of operations is performed in this mill (fig. 3):

1. *Lumber Infeed*
   The lumber starts into the mill on a tilted breakdown hoist. It is rough kiln-dried 4/4 yellow-poplar, in random widths, and in random lengths up to 16 feet.
2. *Conveyor*
   The lumber is unstacked onto a cross conveyor one layer at a time.

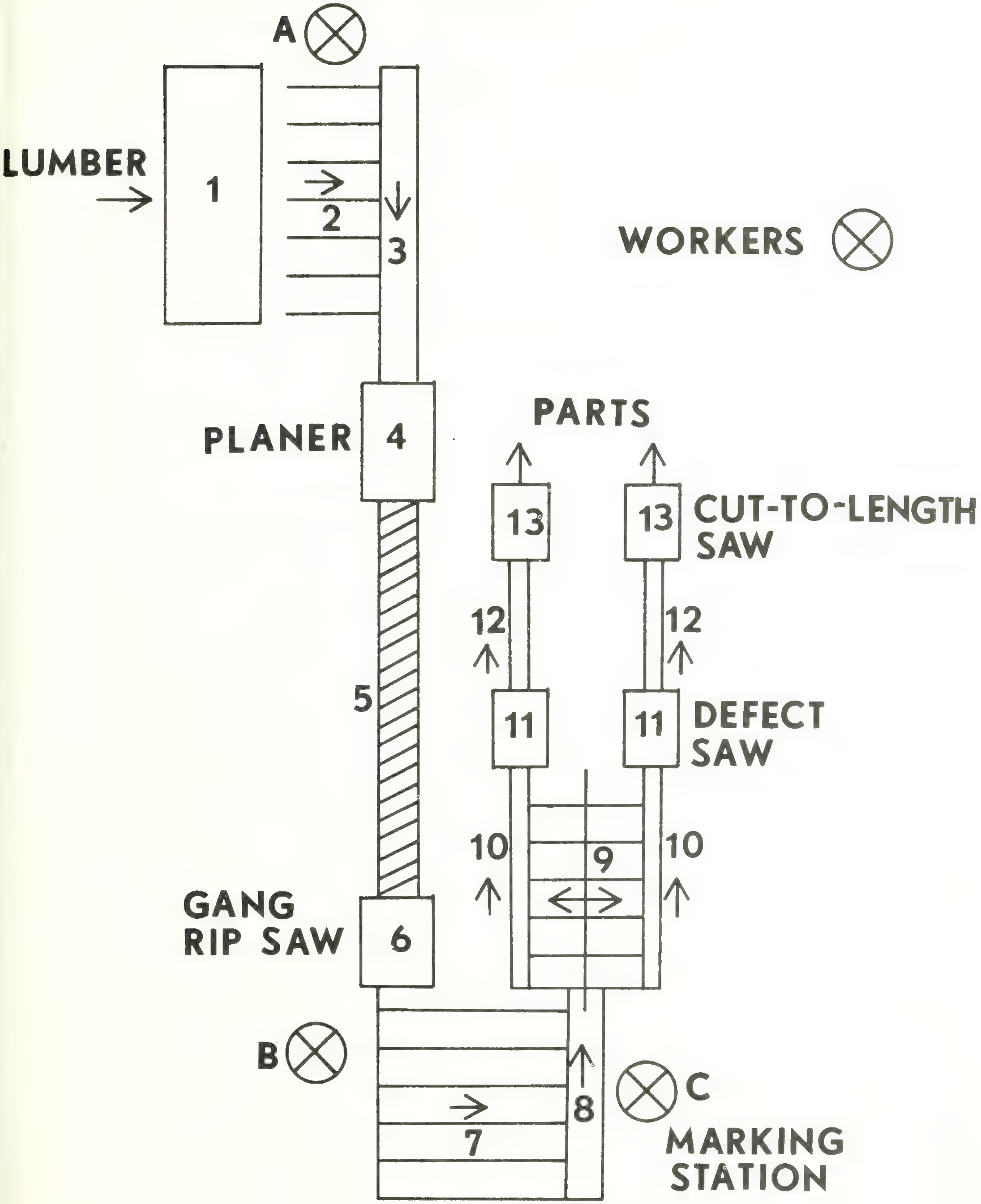
Figure. 2.—The basic operations in the automated mill. In this mill the first operation is to rip the boards into strips, whereas in a conventional mill the boards are crosscut first.



A. *Infeed Station*
   Al is stationed here. He feeds the boards one at a time onto the planer infeed belt at a rate of five boards per minute.

3. *Planer Infeed Belt*
   This is a belt conveyor, 20 feet long. The belt moves at the rate of 100 feet per minute to move the boards into the planer.
4. *Planer*
   The planer surfaces the boards on both sides at the rate of 100 feet per minute. The boards are skip-planed to a standard thickness.
5. *Canted Infeed Rolls*
   Coming out of the planer, the boards go onto a canted roller conveyor that alines

Figure. 3.—Flowchart of operations in the automated interior furniture parts mill.



the boards for feeding into the gang ripsaw. The canted conveyor is 24 feet long and moves at 100 feet per minute.

6. *Gang Ripsaw*
   The gang ripsaw cuts the boards into standard-width strips at the rate of 100 feet per minute.

B. *Offbearer Station*
   Babe is stationed here, at the tail of the ripsaw. Babe moves the edgings off and out of the way. (Wide edgings could be edge-glued and reprocessed or processed into cleat material.)

7. *Cross Conveyor*
   From the tail of the ripsaw, the strips pass onto a cross conveyor that takes the strips over to the marking station. The cross conveyor, 18 feet wide, moves the strips at 25 feet per minute to the defect-marking station.

8. *Marking-Station Conveyor*
   The strips move one at a time onto the marking-station conveyor. The strips are inspected while on this conveyor.

C. *Defect-Marking Station*
   Charlie is stationed here. He quickly marks each strip where it is to be cut to remove defects. If a strip has a defect at the end, such as a split or a knot, he makes a single mark to show where the bad end is to be cut off. If the strip has a defect in the middle, he marks it on both sides for cutting out.

   To mark the strip for cutting, Charlie uses a conducting type of electrolytic solution to make a mark or marks across the strip where he wants the defect cut. Charlie then releases the strip, which travels to one of the two defect saws.

9. *Splitting Bar*
   As Charlie releases each strip, he positions it so the splitting bar guides it toward one of the two defect saws.

10. *Cross Conveyors*
    The cross conveyors then move the strips to one of the two defect saw infeed belts. Two lines, each containing a defect saw and a cut-to-length saw, were required in the mill design (simulated) to achieve the production goal of 4,000 net board feet of interior parts per 8-hour shift from No. 2A Common yellow-poplar lumber.

11. *Automated Defect Saw*
    As the strip moves onto the infeed belt of the defect saw, at 60 feet per minute, an electronic sensing device locates the marks that Charlie made. The fingers of the sensing device, as they feel the mark pass, trip a circuit that activates the automatic saw. The strip is stopped automatically as the mark reaches the saw line, and a clamp holds it momentarily while the saw automatically crosscuts the strip at the mark.

12. *Conveyor*
    Now that the defects have been cut out, the strips are of many different lengths. Some are full length, many shorter. This conveyor carries them at 60 feet per minute to another automated saw where they will be cut to the various lengths needed for interior furniture parts.

13. *Automatic Cut-to-Length Saw*
    The automatic cut-to-length saw can be controlled by a mini-computer or electronic circuit. Before a production run starts, the desired lengths and the number of parts of each length needed are programmed into the controlling device. No operator is required. Cutting is done automatically when a full-length strip or a shorter section of a strip arrives at the automatic cut-to-length saw. At the saw, the following operations are performed automatically.

1. The strip is advanced and is measured for the longest obtainable required lengths.
2. The strip is stopped automatically and crosscut.
3. After the first cut is made, the remaining section of strip is measured and cut to the next longest obtainable required length. This procedure is continued until the remaining section is shorter than the shortest required part.
4. After each cutting, the computer deducts one unit from the quantity needed for that length.
5. When no more cuttings are required, the counter for that length goes to zero.
6. When all cutting requirements have been satisfied, the system stops and is reset for the next run.

After the strips have been cut to the required lengths, they would be moved on to an automatic sorter (not shown in figure 2). Then the parts are shaped to final dimensions by moulding and tenoning.

DISCUSSION

Though the design for this automated rough mill was developed through simulation, it is now at the practical stage for application. All the equipment and devices required are either available now or could be made from components that are available. One furniture manufacturer has installed a mill based on this design.

This automated rough mill design gives manufacturers an automated and highly efficient interior-parts operation. For example, dimension manufacturers who supply several customers, or furniture manufacturers who desire to supply assembly plants from a centralized location, could find it beneficial to establish an automatic cut-to-length interior-parts mill.

The mill has many benefits. In addition to labor savings, high volume, good yields from all grades, and good flow of materials, the mill provides good production control with no overcutting and consistent yields with little chance of operator error.

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Keywords: furniture manufacturing, automatic control

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SETs: Stand Evaluation Tools

I. An Individual-tree Approach to Making Stand Evaluations

by Paul S. DeBald and Joseph J. Mendel

MAR 24

USDA FOREST SERVICE RESEARCH PAPER NE-336
1976
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
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F. BRYAN CLARK, STATION DIRECTOR

SETs

THIS IS ONE of a series of papers designed to help the forester estimate the value of timber stands. We call these papers SETs — Stand Evaluation Tools. The first three papers are being published concurrently. They are:

SETs I. AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS (USDA Forest Service Research Paper NE-336), which describes a method for using individual-tree values to make stand evaluations.

SETs II. TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER (USDA Forest Service Research Paper NE-337), which provides values for individual sawtimber trees.

SETs III. COMPOSITE VOLUME AND VALUE TABLES FOR HARDWOOD PULPWOOD (USDA Forest Service Research Paper NE-338), which provides values for individual growing-stock trees.

ABSTRACT

The authors outline a stand-evaluation method that stresses individuality by (1) making on-the-ground projections of individual tree development; (2) summarizing stand values in terms of the individual trees in the stand and their potential development; and (3) tailoring several management possibilities to an individual stand so the owner can choose among them.

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SETs: Stand Evaluation Tools

I. An Individual-tree Approach to Making Stand Evaluations

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INTRODUCTION

THE SMALL WOODLAND owner can play an important role in meeting our Nation's projected timber needs (*USDA Forest Service 1973*). But he will accept that role only if he decides that he really wants to.

South, Hansbrough, and Bertrand (*1965*) pointed out that a woodland owner is likely to decide to become a timber producer when he becomes aware of the value of his timber and the income potentials from managing his woodland — especially if the income potentials are related to his own individual situation and needs. These potentials might be best expressed in terms of stand values and the changes in value that the stand's owner could expect if he exercised various management options.

OBJECTIVES

Our purpose is to outline a method for making stand evaluations that can be tailored to an individual stand and the individual owner's set of circumstances. The method generates stand values by totaling the values of the individual trees in a stand. It is based on timber quality and changes in timber quality, because quality is the key to timber value. It uses on-the-ground estimates of changes in merchantable height and butt-log grade. Yet, it is a method that can fit in with commonly used timber-cruising procedures.

It is also a method that can be adapted readily to many of the computer programs that have been developed to handle forest-inventory data and to make stand projections. Although we recommend the use of computers for applying the method, our aim in this paper is simply to share the idea of using an individual-tree approach in making stand evaluations. So we chose to avoid locking into any one particular computer program at this time. Instead, we used a desk calculator to make our stand evaluations.

Further, we do not intend at this time to evaluate all the different kinds of stands and all the different kinds of circumstances that surround them and confound them. There are too many. Rather, we will illustrate our procedure with a typical stand in a typical set of circumstances, with the aim of getting the method into the hands of potential users so that they can begin applying it.

GENERAL FRAMEWORK

We suggest making stand evaluations within an accounting type of framework. This general framework includes three accounts:

1. A current stand valuation.
2. A projected stand valuation, assuming that no trees will be cut.
3. One or more projected stand valuations, each representing an assumed cutting alternative.

We also suggest using individual tree values and summing them for stand totals. We do so to stress uniqueness. First, because a tree's value depends on its quality, which in turn depends on the individual tree's unique characteristics. Second, because each stand is a unique grouping of individual trees. We feel that, by relating to trees as individuals, we would be more apt to attract and hold the stand owner's attention. He, too, is unique.

Under the first account we will assign appropriate volumes and values to each tree in a stand and sum them to obtain a current stand valuation. This account will provide estimates of the stand's volume and value right now. It will also provide a base for evaluating the stand's development as described under the other two accounts of the general framework.

Under the second account, we will assume that no cutting will take place; and we will make a 10-year projection of the stand by projecting the diameter, merchantable height, and log quality of each tree in the stand. After assigning appropriate volumes and values to the projected trees, we will sum them to obtain estimates for the projected stand. The 10-year time period will help focus the stand's development within a relatively short and meaningful planning period.

This future stand valuation would reflect the results of exercising the most common management option for the stand — simply letting it grow. Contrasted against the stand's current valuation, this would provide estimates of the changes that we might expect to take place as the stand develops; that is, the changes in its volume and value, and the rates of those changes. We can then compare those changes with the owner's short-run expectations.

Under the third account we will make 10-year projections of the stand, using procedures similar to those above. Here, however, we will investigate the results of cutting the stand under various silvicultural and economic options pertinent to the stand. Taking each option in turn, we will mark the stand, then estimate its future business worth by combining: (1) the volume and value yields of the trees that are marked to be cut, and (2) projected volumes and values of the trees that are to be left.

We will then evaluate each of the cutting options in terms of: (1) the owner's objectives; (2) how it compares with the let-it-grow option; and (3) how it compares with the other cutting options.

FIELD PROCEDURES

For illustration, we used a 1-acre plot and tallied all trees 5.0 inches dbh and larger — 89 of them. Our procedures could also be used with 100-percent inventories of larger tracts, as long as the number of trees does not become burdensome. Or they could be used with representative samples of larger tracts, and the resulting data could be expanded appropriately. We recommend the latter for practical applications.

Our 1-acre plot is located on the Vinton Furnace Experimental Forest in southeastern Ohio. It is a typical oak–hickory stand — second-growth sawtimber on a good site — and it needs thinning. The acre contains a volume of nearly 12,000 board feet (International ¼-inch rule). It has a basal area of 97 square feet.

On our field tally sheet (table 1) we recorded the following data for each tree:

1. Species.
2. Dbh.
3. Merchantable heights for sawlogs and pulpwood.
4. Butt-log grade.
5. Vigor class (See appendix A for definitions).

In addition, we estimated each tree's prospective dbh, merchantable height, and butt-log grade. That is, we made a 10-year projection of each tree, right there on the ground.

We chose to avoid boring a lot of trees — we don't like the job of making increment borings. Instead, we based our estimates of future dbh on regional growth rates (*Holcomb and Bickford 1952; Trimble and Mendel 1969; Grisez and Mendel 1972*). These rates are summarized in appendix B.

We based our estimates of prospective merchantable heights on the likelihood of each tree's adding upper-stem logs or bolts during the next 10 years. And we made our estimates of prospective merchantable height at the same time we estimated each tree's current merchantable height.

In hardwoods, merchantable heights are fixed more often by limbs and forks than they are by minimum diameters. And no matter how much additional diameter growth a tree puts on, it usually cannot increase in sawlog height above the point where its stem breaks into limbs. Thus, we found that most of the trees on our plot — two out of three — would not increase in merchantable height, because of existing limb patterns (table 1). There are a couple of exceptions to this general rule. One is the case of small sawtimber trees without large limbs and excessive taper. The other is the case of poletimber trees, whose minimum top diameters usually limit

Table 1.—Field tally sheet

Plot or Stand: Vinton Furnace #1
Type: Oak-hickory
Size: Sawtimber
Density: Well stocked
Site Index: 80
Stand Age: 70

Tree No.	Species	Present					Projected			
		Dbh	16-foot logs		Butt-log grade	Vigor	Dbh	16-foot logs		Butt-log grade
			Saw-logs	Pulp-wood				Saw-logs	Pulp-wood	
		In.	*No.*	*No.*	*Grade*	*Class*	*In.*	*No.*	*No.*	*Grade*
1	SO	14.7	1½	2½	T&T	2	16.8	1½	2½	3
2	SO	19.3	3	3½	Cull	1	21.7	3	3½	Cull
3	CO	7.6	—	½	—	4	8.2	—	1	—
4	CO	12.1	1½	1½	Cull	3	13.3	1½	1½	Cull
5	WO	7.1	—	1	—	4	7.7	—	1	—
6	SO	17.9	2½	3	T&T	1	20.4	2½	3	2
7	WO	11.7	1	2	3	4	12.2	2	2	3
8	WO	12.6	2½	3½	3	2	14.2	3½	3½	2
9	WO	9.2	—	2	—	4	9.8	—	2	—
10	CO	12.3	1½	2	3	2	14.4	2	2	3
11	BO	14.7	2	2½	2	3	15.8	2	2½	2
12	BO	17.3	2½	2½	2	1	19.8	2½	2½	1
13	BO	13.2	2	2½	3	2	15.3	2½	2½	2
14	WO	11.1	1½	2	3	4	11.7	2	3	3
15	WO	13.4	2	2½	3	2	14.9	2½	2½	2
16	HIC	6.6	—	1	—	4	7.2	—	1½	—
17	WO	15.3	2	2½	2	2	16.7	2½	2½	1
18	WO	13.0	2	3½	3	1	15.0	3½	3½	2
19	WO	9.6	—	2	—	3	10.7	—	2½	—
20	WO	9.4	—	2	—	4	10.0	—	2	—
21	WO	14.7	2	3	3	2	16.2	2	3	2
22	WO	15.0	2½	3	2	1	16.9	3	3	1
23	RO	18.2	2½	2½	2	1	20.7	2½	2½	1
24	WO	14.4	2½	3	2	1	16.4	3	3	2
25	WO	13.4	1½	2½	3	2	14.9	2½	2½	3
26	CO	12.6	1½	2	3	3	13.8	1½	2	3
27	CO	14.6	1½	2½	3	1	17.1	1½	2½	2
28	BO	18.0	3	3	1	1	20.5	3	3	1
29	CO	12.0	1½	2½	T&T	3	13.2	1½	2½	3
30	CO	9.4	—	2½	—	3	10.7	—	2½	—
31	CO	16.1	2½	2½	2	1	18.5	2½	2½	1
32	CO	13.9	2	3	2	1	16.4	2½	3	2
33	BO	16.7	2½	2½	1	1	19.4	2½	2½	1
34	CO	15.0	1½	1½	2	3	16.0	1½	1½	1
35	WO	8.7	—	2	—	4	9.3	—	2	—
36	CO	12.4	1	2	3	4	13.0	1½	2	3
37	CO	16.0	2	3	2	2	17.8	2	3	1
38	RM	6.6	—	1	—	3	8.5	—	1½	—
39	WO	10.4	—	2½	—	2	12.1	1½	3	3
40	RM	5.4	—	½	—	4	7.3	—	1½	—
41	CO	9.1	—	1½	Cull	4	9.7	—	1½	—
42	CO	12.1	1	1½	3	3	13.3	1½	1½	3
43	CO	12.8	1	2½	3	2	14.9	1	2½	3
44	RO	25.1	2½	2½	1	1	27.1	2½	2½	1
45	CO	13.1	1½	2	3	3	14.2	1½	2	3

CONTINUED

Table 1—Continued

Tree No.	Species	Present					Projected			
		Dbh	16-foot logs		Butt-log grade	Vigor	Dbh	16-foot logs		Butt-log grade
			Saw-logs	Pulp-wood				Saw-logs	Pulp-wood	
46	HIC	5.7	—	1	—	3	7.2	—	2½	—
47	ASH	10.9	—	1½	—	3	12.0	1½	1½	3
48	CO	8.0	—	1½	—	3	9.2	—	1½	—
49	WO	12.0	1½	3	3	2	13.6	2	3	3
50	WO	18.3	2½	3	2	1	20.1	2½	3	2
51	WO	15.6	2½	3½	2	1	17.0	2½	3½	1
52	WO	9.8	—	1½	—	4	10.4	—	1½	—
53	WO	9.2	—	2	—	4	9.8	—	2	—
54	WO	17.6	3½	3½	1	1	19.4	3½	3½	1
55	WO	11.2	1	2½	3	3	12.3	1½	2½	3
56	YP	7.6	—	2	—	3	9.0	—	2	—
57	BO	20.2	3	3½	1	1	22.6	3	3½	1
58	SO	19.6	3	3	1	1	22.0	3	3	1
59	WO	17.4	3	3	1	1	19.2	3	3	1
60	BO	11.9	1½	2½	3	3	13.2	2	2½	3
61	CO	12.7	1½	1½	3	4	13.3	1½	1½	3
62	WO	18.8	2½	3	1	1	20.6	2½	3	1
63	WO	13.9	2½	3	2	2	15.4	2½	3	2
64	BO	17.9	1½	1½	2	1	20.4	1½	1½	1
65	WO	10.9	—	2	—	3	12.1	1½	2	3
66	WO	16.5	1½	2	Cull	4	17.0	1½	2	Cull
67	WO	11.0	1½	2½	3	3	12.1	1½	2½	3
68	WO	7.4	—	1	—	4	8.0	—	1½	—
69	WO	14.0	2	2½	2	3	15.1	2½	2½	2
70	BO	22.7	2½	2½	1	1	24.9	2½	2½	1
71	WO	21.2	3½	3½	1	2	22.4	3½	3½	1
72	WO	13.2	1½	2½	3	3	14.3	2	2½	2
73	WO	10.7	—	2	—	3	11.9	1½	2	3
74	WO	13.6	2	2½	3	3	14.7	2	2½	2
75	WO	12.8	2	2½	3	2	14.4	2	2½	3
76	BO	17.1	2½	3	1	2	19.0	2½	3	1
77	WO	7.6	—	1½	—	4	8.2	—	2	—
78	WO	13.7	2	2	3	2	15.2	2	2	2
79	CO	17.9	1½	1½	1	1	20.1	1½	1½	1
80	RO	25.0	2	2	1	2	26.5	2	2	1
81	BO	19.7	3	3	1	2	21.5	3	3	1
82	BO	13.7	1½	2½	3	3	14.8	2	2½	3
83	WO	17.0	3	3½	2	2	18.4	3	3½	2
84	CO	10.9	—	1½	—	2	13.1	1	1½	3
85	WO	8.9	—	2	—	4	9.5	—	2	—
86	WO	8.3	—	2	—	4	8.9	—	2	—
87	BO	19.7	2	2	1	1	22.1	2	2	1
88	YP	7.6	—	1½	—	3	9.2	—	2	—
89	WO	16.6	2	3	2	1	18.5	2½	3	2

merchantability. In these instances we estimated prospective merchantable heights by considering each tree's taper and visually projecting its upper stem diameters.

Regardless of whether limbs or minimum diameters are the limiting factors, the only place to estimate a tree's current merchantable height is right there on the ground. It is also the best place to estimate its prospective merchantable height.

This do-it-yourself-while-you-are-out-there approach also applies to estimating timber quality. We used it to estimate the prospective butt-log grade of each tree. And, as with prospective merchantable heights, we estimated the prospective butt-log grade of each tree at the same time we assigned it a current butt-log grade.

In judging potential changes in butt-log grade we did, of course, consider such external grading features as branches and knots. We also considered minimum top diameters — more so than we did with merchantable heights. That's because of the diameter thresholds that are built into the standard grades (*Rast and others 1973*).

We found that a number of trees were limited in butt-log grade solely by their top diameters, and that we could expect some of them to improve in grade as they grew in diameter during the next 10 years. All in all, we estimated that one-third of sawtimber trees would improve in grade. Included in the other two-thirds were 15 trees that already have grade-1 butt logs and thus could not improve within the grading system that we limited ourselves to.

We are aware that our on-the-ground projections of merchantable heights and butt-log grades are not foolproof. Indeed, they were subjective. But at least they were not mechanical. Because we made them one tree at a time and based them on each tree's own characteristics, we did so with reasonable confidence.

OFFICE PROCEDURES

Evaluating Stand Development

We made valuations of our present and projected stands by assigning appropriate values to the individual trees in the stand. Here we define values as numerical quantities, not just dollar quantities. They include board-foot and cord volumes, basal areas, and dollar values.

For volumes we used the Lake States Composite Volume Tables (International ¼-inch rule), because their composite nature makes them applicable to a variety of species. For dollar values we used tree-value conversion standards. Those for sawtimber are from TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER (*Mendel, DeBald, and Dale 1976*). Those for pulpwood (at $1.50 per cord) are from COMPOSITE VOLUME AND VALUE TABLES FOR HARDWOOD PULPWOOD (*DeBald and Mendel 1976*). Briefly, these standards reflect a tree's net worth as 4/4-inch lumber and/or pulpwood; we assumed that the tree would be converted into one or both of those products in an integrated logging operation and allowed for the cost of conversion.

It is obviously appropriate to apply the same volume and basal-area standards to both our present stand and our projected stand. But there may be some question about applying current dollar-value standards to our future stand. We can answer by pointing out that our goal is to evaluate the stand's development and not to fix the stand's absolute future value. By using the same dollar value base at both ends of the projection period, we can focus directly on the biological development of the stand without letting valuation items irrelevant to biological change get in the way.

We used an extension of our field tally sheet to make our stand valuations (table 2). We listed each tree's basal area, board-foot, cord, and dollar value and summed them for stand totals.

At this point we have valuations for both our present stand and the stand that would result if we simply let it grow.

	Basal area per acre (square feet)	*Volume (board feet)*	*Value (dollars)*
Present	97	11,627	$465.44
Projected	119	15,590	$770.75

These valuations give us yardsticks for gaging the stand's development and its potential value. But before we use those yardsticks, let's check the effectiveness of the on-the-ground projections we used to develop them.

Testing Our Projections (Or, How Wrong Can We Be?)

We certainly don't want to wait for 10 years to judge our estimates of prospective heights and grades. But we can weigh now the implications of having made errors in our estimates. The following does so; but keep in mind that it applies to only this plot.

Obviously, the worst we could have done was to have estimated wrong every time. We

Table 2.—Tree values

Tree No.	Present				Projected			
	Basal area	Volume		Tree value	Basal area	Volume		Tree value
	Sq. ft.	*Bd. ft.*	*Cords*	*Dollars*	*Sq. ft.*	*Bd. ft.*	*Cords*	*Dollars*
1	1.18	123	0.357	$0.54	1.54	162	0.472	$3.81
2	2.03	—	.768	1.15	2.57	—	.983	1.47
3	.32	—	.027	.04	.37	—	.053	.08
4	.80	—	.164	.25	.96	—	.199	.30
5	.27	—	.040	.06	.32	—	.047	.07
6	1.75	275	.604	.91	2.27	366	.794	19.78
7	.75	54	.191	.29	.81	104	.208	.31
8	.87	126	.317	.48	1.10	202	.406	.61
9	.46	—	.116	.17	.52	—	.132	.20
10	.83	85	.211	.32	1.13	148	.292	.60
11	1.18	157	.305	3.84	1.36	176	.415	5.10
12	1.63	255	.501	8.20	2.14	343	.665	24.12
13	.95	122	.286	1.17	1.28	196	.388	4.83
14	.67	69	.171	.26	.75	95	.250	.38
15	.98	127	.295	.44	1.21	186	.368	1.54
16	.24	—	.034	.05	.28	—	.057	.08
17	1.28	166	.388	2.13	1.52	235	.466	10.39
18	.92	118	.277	.51	1.23	232	.455	1.13
19	.50	—	.127	.19	.62	—	.186	.28
20	.48	—	.122	.18	.55	—	.138	.21
21	1.18	154	.401	.60	1.43	186	.491	3.33
22	1.23	188	.418	1.81	1.56	278	.536	11.16
23	1.81	285	.557	12.83	2.34	378	.729	31.00
24	1.13	173	.384	1.07	1.47	261	.503	3.65
25	.98	102	.295	.44	1.21	186	.368	.55
26	.87	90	.222	.33	1.04	107	.268	.40
27	1.16	121	.352	.82	1.59	168	.489	4.38
28	1.77	320	.611	17.90	2.29	425	.802	28.34
29	.79	80	.235	.35	.95	99	.286	.43
30	.48	—	.142	.21	.62	—	.186	.28
31	1.41	216	.432	3.72	1.87	296	.577	15.19
32	1.05	138	.357	1.83	1.47	226	.503	4.21
33	1.52	235	.466	13.40	2.05	328	.637	22.50
34	1.23	128	.255	2.25	1.40	147	.292	7.70
35	.41	—	.104	.16	.47	—	.119	.18
36	.84	61	.215	.32	.92	96	.237	.36
37	1.40	180	.478	3.58	1.73	230	.597	12.55
38	.24	—	.034	.05	.39	—	.079	.12
39	.59	—	.175	.26	.80	82	.268	.40
40	.16	—	.014	.02	.29	—	.058	.09
41	.45	—	.091	.14	.51	—	.104	.16
42	.80	58	.164	.25	.96	100	.199	.30
43	.89	66	.268	.40	1.21	91	.368	.64
44	3.44	560	1.109	57.10	4.01	655	1.299	70.96
45	.94	97	.240	.36	1.10	114	.284	.47
46	.18	—	.025	.04	.28	—	.083	.12
47	.65	—	.132	.20	.79	80	.161	1.92
48	.35	—	.070	.11	.46	—	.093	.14
49	.79	80	.264	.40	1.01	131	.341	.51
50	1.83	289	.632	7.51	2.20	354	.770	12.44
51	1.33	203	.493	2.44	1.58	245	.590	11.40
52	.52	—	.106	.16	.59	—	.120	.18
53	.46	—	.116	.17	.52	—	.132	.20
54	1.69	342	.634	13.33	2.05	423	.777	20.85
55	.68	50	.204	.31	.83	85	.247	.37

CONTINUED

Table 2.—Continued

Tree No.	Present				Projected			
	Basal area	Volume		Tree value	Basal area	Volume		Tree value
	Sq. ft.	*Bd. ft.*	*Cords*	*Dollars*	*Sq. ft.*	*Bd. ft.*	*Cords*	*Dollars*
56	.32	—	.079	.12	.44	—	.111	.17
57	2.23	410	.845	26.91	2.79	522	1.070	39.66
58	2.10	384	.730	27.37	2.64	495	.930	41.29
59	1.65	297	.569	12.78	2.01	368	.699	19.63
60	.77	79	.231	.68	.95	122	.286	1.17
61	.88	91	.181	.27	.96	100	.199	.30
62	1.93	307	.669	17.38	2.31	374	.810	25.04
63	1.05	160	.357	.97	1.29	198	.442	2.32
64	1.75	186	.369	7.09	2.27	246	.484	21.19
65	.65	—	.165	.25	.80	82	.204	.31
66	1.48	—	.388	.58	1.58	—	.413	.62
67	.66	68	.197	.29	.80	82	.239	.36
68	.30	—	.043	.06	.35	—	.070	.11
69	1.07	140	.323	1.00	1.24	190	.378	1.92
70	2.81	458	.886	37.92	3.38	550	1.090	49.60
71	2.45	515	.936	30.70	2.74	577	1.051	38.37
72	.95	99	.286	.43	1.12	146	.338	1.22
73	.62	—	.159	.24	.77	79	.197	.30
74	1.01	131	.304	.46	1.18	154	.357	1.56
75	.89	114	.268	.40	1.13	148	.342	.51
76	1.59	248	.549	14.65	1.97	314	.684	21.12
77	.32	—	.063	.09	.37	—	.092	.14
78	1.02	133	.264	.40	1.26	164	.327	1.84
79	1.75	186	.369	10.88	2.20	239	.470	15.66
80	3.41	470	.960	50.21	3.83	530	1.085	59.19
81	2.12	388	.738	24.54	2.52	472	.886	33.50
82	1.02	106	.309	1.46	1.19	156	.362	2.18
83	1.58	281	.590	4.86	1.85	336	.695	8.20
84	.65	—	.132	.20	.94	69	.193	.29
85	.43	—	.109	.16	.49	—	.124	.19
86	.38	—	.094	.14	.43	—	.109	.16
87	2.12	286	.562	21.89	2.66	365	.715	31.69
88	.32	—	.063	.09	.46	—	.116	.17
89	1.50	197	.516	3.92	1.87	296	.647	8.00
Total	97.12	11,627	29.299	465.44	119.31	15,590	36.782	770.75

tested this supposition by remaking our projections of each tree's merchantable height and butt-log grade, purposely introducing errors, except for trees that have grade-1 butt logs right now and trees that would be limited in grade by minimum diameters (we assumed no change in them).

For example, in our original projection we may have estimated that a particular tree would remain at 2 logs. We *re-projected* it to 2½ logs. Or, if we had estimated that a tree's butt log would improve from grade 3 to grade 2, we remade our projection to show that it would remain in grade 3.

Such errors would, of course, make big differences for many individual trees, on a tree-by-tree basis. But by summing individual tree values to obtain stand totals, we found that the differences tended to net out.

If we had estimated every future merchantable height wrong, we would have projected our stand's future volume to 17,609 board feet, a net difference that is 8 percent higher. That is because, in our re-projection, we would have underestimated the heights of trees with small diameters and small volumes, and would have overestimated the heights of trees with large diameters and large volumes.

The difference in projected dollar values would be a lot smaller. Even if we had estimated all our future heights wrong, we would show a projected dollar value for the entire stand that was only 6 percent higher than our original projection. If we had been wrong on future grades every time possible, we would show a difference that was 6 percent lower. This would have offset our errors in height. Thus, had we erred every time in our estimates of change in height and grade, the overall difference in stand value between the right and wrong projections would be less than 1 percent.

STAND EVALUATIONS

Current Stand Valuation

As noted earlier, we estimated our stand's current value at $465. This is not a stumpage value, because it makes no allowance for a prospective buyer's profit and risk or bargaining skill. Nor does it reflect current local demands for timber. Rather, it is a conversion value, based on average regional prices and conversion costs at a particular time (1972). It is a standard measure and a starting point for making stand evaluations.

The matter of placing a dollar value on the stand is, in itself, important. For, in many cases, forest land owners are apathetic to the idea of practicing timber management, simply because they are not aware of their timber's value. But when they do learn of its value, they often become interested in further developing the income potential of their forest land. We suggest this as a first step in encouraging woodland owners to adopt management practices.

Let-Grow Projections

When we make our stand evaluations, we need to consider, first, the results that we can expect if we just let the stand grow. This let-grow option is the option that is most commonly adopted by forest land owners. And it's the one that gives us a yardstick for measuring the stand's development.

We should, however, emphasize two things about our estimate of future stand value. First, it is not an estimate of future stumpage value. Like our current stand value, it is based on conversion value standards. Second, the conversion value standards have 1972 lumber prices built into them. Thus our estimate of future stand value is not an estimate of actual future worth. Instead, and more important, it is a dollar estimate of our stand's development that is tied directly to the biological development of the individual trees in the stand and is measured with the same units that we used for our estimate of the stand's current value. For these reasons we can make some direct comparisons between our current and future stand and some meaningful evaluations of the stand's development, even though we are not attempting to fix, absolutely, the stand's future value.

Our forecast for our sample acre indicates that, if we simply let it continue to grow for 10 more years, it will then have a volume of more than 15,000 board feet. This would be an increase of nearly 4,000 board feet, or an average annual increase of 3.4 percent. During the same period our stand's value would increase by more than $300 and amount to $771. We would thus expect our stand to increase in value at a rate of 5.2 percent, compounded annually.

The stand owner must judge for himself the acceptability of the size and rate of this projected value increase. He would ordinarily base his judgment on a number of outside factors and on how he views them within his own circumstances. If he is satisfied with the size and rate of the value increase, he might well be content to sit back and let his stand grow. But, if he is not satisfied with them, he might want to do something about it. In any case, he should be aware of the options open to him.

One obvious thing the owner could do is liquidate his timber and invest the proceeds at some higher alternative rate. But he has other choices, too. He could lower his financial expectations and rationalize them in view of whatever other reasons he may have for maintaining ownership of the timber. Or he could look for ways to improve the stand's income potential. If so, he would be willing to at least listen to some arguments that point out the benefits of adopting silvicultural treatments.

Here is where timing is important. We have, so far, limited our evaluation to a 10-year period. It would be logical to frame evaluations of stand treatments within the same time period. This would not only facilitate comparisons; it would also help clear a lot of the murk that we often expect forest landowners to see through when we are promoting good forestry. If we can convince the owner that he can expect some acceptable results within a 10-year period, he would be more inclined to accept our assurances of longer-range benefits.

Of course, we can't show that good forestry pays every time and in every case. In some cases we will be able to point out great benefits from stand treatment; in others, only slight benefits, which may or may not be enough to encourage the owner. In still others we will have to admit to the cost of practicing recommended forestry. And many times we won't know which case is which until we evaluate a particular treatment. But even then the choice of adopting it lies with the owner.

Cutting Projections

Our current stand, with 97 square feet of basal area, is well stocked. According to regional standards, recommended stocking would be about 70 square feet (*Gingrich 1971*). Thus our stand could be partially cut to increase the growth of crop trees and, if even-aged management is envisioned, to condition the stand for a harvest cut.

The stand could be cut in several ways. We will consider four of them, using:

1. An even-aged approach in which we would carry the main stand through a series of periodic thinnings until it was mature and ready for harvest. Our first thinning in this particular stand would include large culls, biologically mature trees, and small culls, in that order (*Roach and Gingrich 1962*).
2. An all-aged approach in which we would periodically remove selected individual trees throughout the whole range of diameters. Our first cutting in this stand would include culls, trees that are silviculturally undesirable, and trees that are financially mature (*Trimble and others 1974*).
3. A high-grade cutting in which we would remove trees with the highest value and leave those with the lowest value. In this stand such a cutting, a form of high-grading, would approximate a diameter-limit cutting.
4. A low-grade cutting in which we would remove trees with the lowest value and leave those with the highest value.

Taking each cutting option in turn, we made a cut-and-leave tally for our sample acre. In doing so, we assumed that our *leave* trees would grow at the same rate under a cutting option as they would under the let-grow option. We made no effort to allow for increased growth at lower residual densities. In actual practice, such increases are likely and should be expected. So our estimates for the future stands under the cutting options are conservative.

The results we would expect from the above cuttings are summarized in table 3. It also summarizes the results we would expect if we exercised either the let-grow or the harvest-now options.

Note that we would remove approximately the same basal area in each of the cuttings and, of course, leave about the same basal area in each so as to approximate full site utilization. Note, too, that our expected future basal areas would be nearly the same.

But look at the big differences in board-foot volumes and dollar values. If we removed only low-value trees, our cutting would be practically noncommercial in terms of both board-foot volume and dollar value. But it would result in a high-valued stand in 10 years. If we made a high-grade cutting, we would sacrifice future value for a big return right now. With an even-aged approach, our first thinning in this stand would be pretty well concentrated in mature trees in the upper diameters. But with an all-aged approach, we would cut trees throughout the range of diameters. Thus our even-aged cutting would remove more volume and value now, and our

Table 3.—Treatment comparisons

Option	Cut			Leave			Projected stand		
	Basal area	Volume	Value	Basal area	Volume	Value	Basal area	Volume	Value
	Sq. ft.	*Bd. ft.*	*Dollars*	*Sq. ft.*	*Bd. ft.*	*Dollars*	*Sq. ft.*	*Bd. ft.*	*Dollars*
Let-grow	—	—	—	97	11,627	$465.44	119	15,590	$770.75
Harvest now	97	11,627	$465.44	—	—	—	—	—	—
Partial cut:									
Even-aged	25	3,471	278.76	72	8,156	186.68	89	11,394	403.94
All-aged	26	2,416	167.85	71	9,211	297.59	90	12,705	558.96
High-grade	26	4,346	326.57	71	7,281	138.87	88	10,311	331.99
Low-grade	25	1,295	9.19	72	10,332	456.25	89	13,388	754.90

Table 4.—Treatment yields

Option	Overall		Net		Rate-of-value increase
	Volume	Value	Volume	Value	
	Bd. ft.	*Dollars*	*Bd. ft.*	*Dollars*	*Percent*
Let-grow	15,590	$770.75	3,963	$305.31	5.2
Harvest now	11,627	833.53	—	368.09	6.0
Partial cut:					
Even-aged	14,865	903.16	3,238	437.72	6.9
All-aged	15,121	859.55	3,494	394.11	6.3
High-grade	14,657	916.83	3,030	451.39	7.0
Low-grade	14,683	771.36	3,056	305.92	5.2

all-aged cutting would result in more volume and value 10 years from now.

The yields that we might expect from each of our options are summarized in table 4. Here the overall board-foot yield for each option is the present volume in trees that would be cut under that option, plus the projected volumes of the trees that would be left. The overall dollar yield of each option is its cut value, compounded at a moderate 6 percent for 10 years, plus the projected values of the trees in the future stand. The net yields were found by subtracting the stand's present volume and value from the overall yields of each option. And the rate-of-value increase for each option is the interest rate that corresponds to the ratio of the overall value yield in 10 years and the stand's present value.

Note that the board-foot yields would not vary greatly from one cutting option to another, but that each of them would be lower than the board-foot yield from let-grow option. Remember, we did not allow for residual densities in our growth estimates. But note, too, that the dollar value yields would be fairly similar in each of the three commercial cuttings and that each of them would exceed the dollar value yield from either the let-grow or the harvest-now options. Even the low-grade cutting would yield more value than the let-grow option.

In each of the cuttings we would remove many trees that are increasing in value at rates less than 6 percent, and re-invest their present value at a 6-percent rate. Thus, with each of the cuttings, our stand would display a rate-of-value increase that is higher than the rate we would expect from the let-grow option. And, here too, the three commercial cutting options would increase in value at similar rates.

The choice of which cutting option is best depends, of course, on the owner and his individual situation. The high-grade cutting does have a slightly higher dollar yield, but this can be expected in the short run. Repeated cutting of this type is, nonetheless, continued high-grading and will have an adverse silvicultural effect in the long run (*Trimble 1971*).

The important thing is that we can show the owner how cutting could improve his stand's value yield during the next decade, even if he chooses to make a noncommercial thinning. So he just might be willing to listen to additional arguments that emphasize the longer-range benefits of practicing silviculture.

As a clincher we could point out that our comparisons are conservative (pessimistic might be a better word). We must emphasize, again, that we used the same set of diameter growth rates in each of our projections. These rates were developed from data that had been collected in unmanaged stands, and we did not adjust the rates to changes in residual-stand density.

Actually, we would expect the diameter growth rates of many residual trees to increase under the cutting options. But we really don't know how much of a response to expect, especially in terms of individual trees.

We could be completely optimistic and assume that, as a result of a cutting, every residual tree will increase in vigor and will grow faster than it would have in the unthinned stand. But this is not likely. We could be moderately optimistic and assume that perhaps half of the residual trees will increase in vigor. Yet we can't say which ones.

Instead, we will emphasize the point that our estimates are conservative, that the owner can expect somewhat higher yields from his cutting options, and that the degree of optimism is up to him. After all, they are his trees. And optimism is what we thrive on.

IN SUMMARY SOME PHILOSOPHY

Each tree is unique. So is each stand. So is each woodland owner. Each deserves recognition as an individual.

We recommend stressing individuality, in promoting timber management. We suggest using an evaluation approach that refers to the individual trees in a particular stand and allows the stand owner to relate their development to his own particular circumstances.

In our approach we recognize tree individuality, even to the point of making on-the-ground projections of each tree's development, based on each tree's own unique characteristics. We recognize stand individuality by summarizing our sample stand's values in terms of the individual trees in the stand and their potential development. And we recognize woodland owner individuality by tailoring several treatment possibilities to the owner's individual stand, by focusing treatment results within a relatively short planning period, and by reserving for the owner the choice to do as he sees fit.

We sense that such an approach would provide timber owners with an improved basis for deciding to become timber producers.

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APPENDIX A

DEFINITION OF VIGOR CLASSES

Vigor I. — A tree in this vigor class has a large, healthy, full crown in a dominant or codominant position. Half the crown or more is exposed to direct sunlight. The crown is typically dense, with no evidence of disease or mechanical injury. The bark and twigs have good color.

Vigor II. — A tree in this vigor class has a fair-size crown in a codominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and less perfect than that of a vigor-I tree. This class may also include a large-crowned or dominant tree that otherwise fails to meet the requirements for vigor I.

Vigor III. — A tree in this vigor class has a medium to small crown of intermediate position. Only the top is exposed to direct sunlight. The crown may be open, with some dead or broken limbs. This class also includes trees that have fair to large crowns in a codominant position but cannot meet requirements for vigor I and vigor II. It may also include overtopped trees of a tolerant species that have dense crowns of good color.

Vigor IV. — A tree in this class usually has a small crown in an overtopped position. This class includes all living trees that fail to meet the requirements of the higher vigor classes.

APPENDIX B

Table 5.—10-year diameter growth rates, in inches

Dbh	Vigor 1	Vigor 2	Vigor 3	Dbh	Vigor 1	Vigor 2	Vigor 3
	RED OAK[1]				YELLOW-POPLAR[2]		
12	3.0	2.2	1.2	12	2.9	2.1	1.4
14	2.8	2.1	1.1	14	2.8	2.0	1.3
16	2.7	2.0	1.1	16	2.6	1.9	1.2
18	2.5	1.9	1.0	18	2.5	1.8	1.2
20	2.4	1.8	1.0	20	2.4	1.7	1.1
22	2.2	1.7	.9	22	2.3	1.7	1.1
24	2.1	1.6	.9	24	2.2	1.6	1.0
26	2.0	1.5	.8	26	2.1	1.5	1.0
28	1.8	1.4	.7	28	1.9	1.4	.9
30	1.6	1.2	.7	30	1.8	1.3	.8
32	1.5	1.1	.6	32	1.7	1.2	.8
	WHITE OAK[1]				RED MAPLE[3]		
12	2.1	1.6	1.1	12	2.5	2.0	1.7
14	2.0	1.5	1.1	14	2.5	2.0	1.6
16	1.9	1.4	1.0	16	2.4	2.0	1.5
18	1.8	1.4	1.0	18	2.4	2.0	1.3
20	1.7	1.3	.9	20	2.4	2.0	1.2
22	1.6	1.2	.8	22	2.3	2.0	1.1
24	1.5	1.1	.8	24	2.3	1.9	.9
26	1.4	1.1	.7	26	2.2	1.9	.8
28	1.3	1.0	.7	28	2.2	1.9	.7
30	1.2	.9	.6	30	2.2	1.9	.5
32	1.1	.8	.6	—	—	—	—
	CHESTNUT OAK[1]				WHITE ASH[3]		
12	2.7	2.1	1.2	12	2.0	1.7	1.1
14	2.5	1.9	1.1	14	2.1	1.7	1.1
16	2.4	1.8	1.0	16	2.2	1.7	1.1
18	2.2	1.7	.9	18	2.2	1.7	1.1
20	2.1	1.6	.9	20	2.3	1.7	1.1
22	2.0	1.5	.9	22	2.3	1.7	1.2
24	1.9	1.4	.8	24	2.4	1.7	1.2
26	1.8	1.3	.8	26	2.4	1.7	1.2
28	1.6	1.2	.7	28	2.5	1.7	1.2
30	1.5	1.1	.6	30	2.5	1.7	1.2
32	1.4	1.1	.6	—	—	—	—

[1] Trimble and Mendel 1969.

[2] Holcomb and Bickford 1952.

[3] Grisez and Mendel 1972.

Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

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- Warren, Pennsylvania.

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1976. **An individual-tree approach to making stand evaluations. (SETs: Stand Evaluation Tools. 1.)** Northeast For. Exp. Stn., Upper Darby, Pa.
13 p. (USDA For. Serv. Res. Pap. NE-336)

The authors outline a stand-evaluation method that stresses individuality by (1) making on-the-ground projections of individual tree development; (2) summarizing stand values in terms of the individual trees in the stand and their potential development; and (3) tailoring several management possibilities to an individual stand so the owner can choose among them.

624.1 + 653 + 644.2 + 644.6

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SETs: Stand Evaluation Tools

II. Tree Value Conversion Standards for Hardwood Sawtimber

by Joseph J. Mendel
Paul S. DeBald
and Martin E. Dale

USDA FOREST SERVICE RESEARCH PAPER NE-337

1976

FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
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F. BRYAN CLARK, STATION DIRECTOR

SETs

THIS IS ONE of a series of papers designed to help the forester estimate the value of timber stands. We call these papers SETs — Stand Evaluation Tools. The first three papers are being published concurrently. They are:

SETs I. AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS (USDA Forest Service Research Paper NE-336), which describes a method for using individual tree values to make stand evaluations.

SETs II. TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER (USDA Forest Service Research Paper NE-337), which provides values for individual sawtimber trees.

SETs III. COMPOSITE VOLUME AND VALUE TABLES FOR HARDWOOD PULPWOOD (USDA Forest Service Research Paper NE-338), which provides values for individual growing-stock trees.

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SETs: Stand Evaluation Tools

II. Tree Value Conversion Standards for Hardwood Sawtimber

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FOREWORD

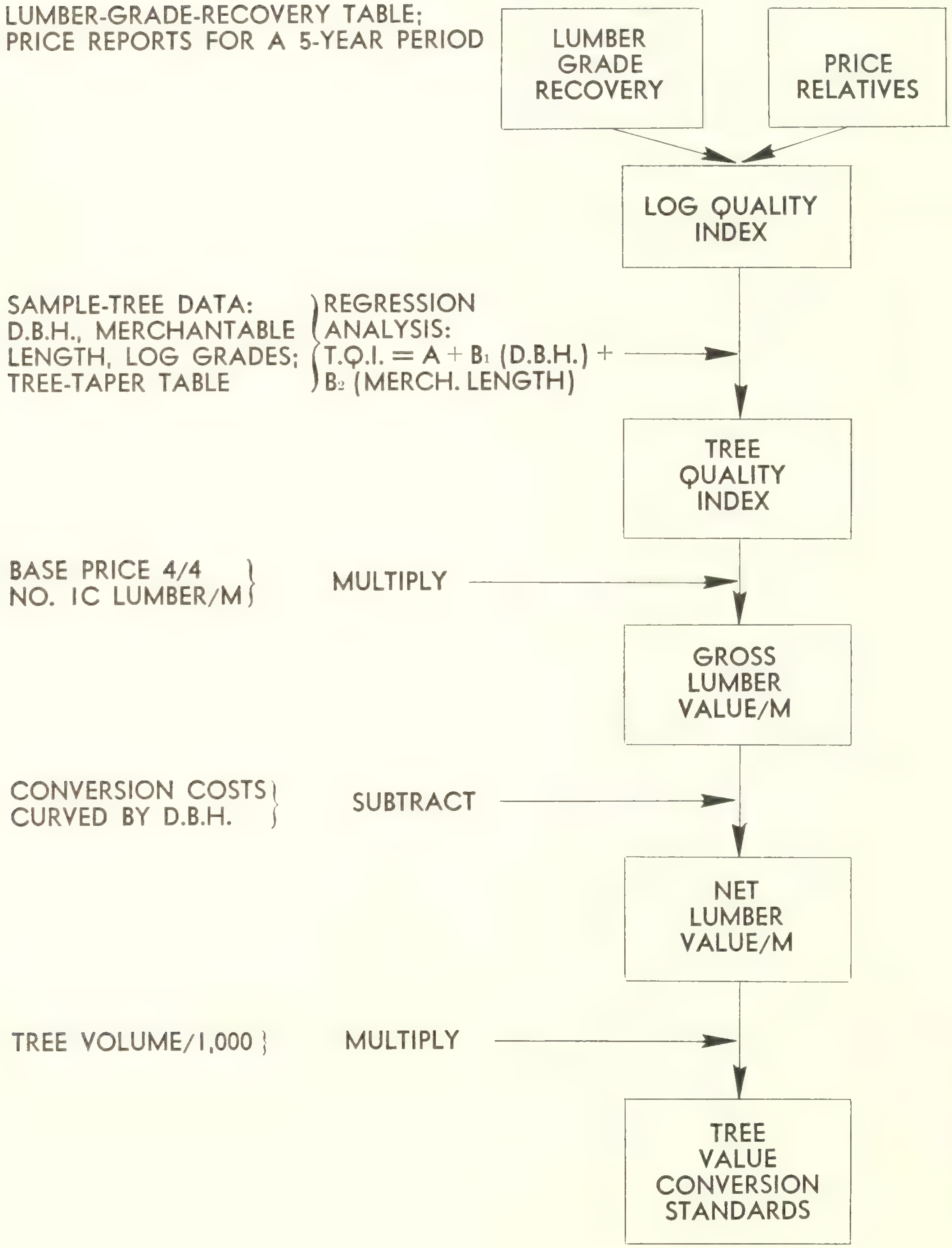
In the past it has been customary to base estimates of probable profits from the management of lands for the future production of timber in the United States upon the increase of the timber in quantity. Everyone familiar with the lumber business knows, however, that the lumber which comes out of large trees is worth more per thousand feet than that which comes from small trees, because the large trees turn out a higher proportion of the choice grades. It is apparent that estimates of profits through careful forest management should take into account this factor of quality increase; but, in the absence of an accurate determination of what this quality increase is, it has hitherto been impossible to do more than state in general terms the fact that such an increase would take place and that its effect would be to make the profit from deferred operations greater than that actually shown by the figures indicating the future yield to be expected.

—Edward A. Braniff in the 1904 Yearbook of Agriculture

ABSTRACT

Tree quality index tables are presented for 12 important hardwood species of the oak-hickory forest. From these, tree value conversion standards are developed for each species, log grade, merchantable height, and diameter at breast height. The method of calculating tree value conversion standards and adapting them to different conditions is explained. A computer program for calculating tree values for different lumber values and conversion costs is included.

Figure 1. — Calculation of tree value conversion standards


LUMBER-GRADE-RECOVERY TABLE; PRICE REPORTS FOR A 5-YEAR PERIOD
LUMBER GRADE RECOVERY
PRICE RELATIVES
LOG QUALITY INDEX
SAMPLE-TREE DATA: D.B.H., MERCHANTABLE LENGTH, LOG GRADES; TREE-TAPER TABLE
REGRESSION ANALYSIS: T.Q.I. = A + B₁ (D.B.H.) + B₂ (MERCH. LENGTH)
TREE QUALITY INDEX
BASE PRICE 4/4 NO. 1C LUMBER/M
MULTIPLY
GROSS LUMBER VALUE/M
CONVERSION COSTS CURVED BY D.B.H.
SUBTRACT
NET LUMBER VALUE/M
TREE VOLUME/1,000
MULTIPLY
TREE VALUE CONVERSION STANDARDS

INTRODUCTION

IN RECENT YEARS the USDA Forest Service has published a series of papers that deal with the rates of value increase for most of the important hardwood species (see References). An important part of these computations is a system for generating individual values for sawtimber trees. The system and the values both have a lot of potential uses for evaluating timber stands and their development. And so, in this paper we: a) describe fully the value system, b) present a set of sawtimber tree values, c) show how the values can be applied, and d) describe a computer program for generating tree volumes and tree value conversion standards. In doing so, our aim is to provide researchers and practitioners with a means for making rigorous timber evaluations.

To further that aim, we are publishing concurrently two other papers — COMPOSITE VOLUME AND VALUE TABLES FOR HARDWOOD PULPWOOD and AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS. These three papers combined make a useful set of working tools.

TREE VALUE CONVERSION STANDARDS . . .

What They Are

Tree value conversion standards (TVCS) are a measure of a tree's worth in dollars, based on the quantity and quality of its expected yield of 4/4 (1-inch) lumber. They are standards, not in the sense that they are fixed and absolute values, but in the sense that they are criteria for gaging tree value within a given framework of circumstances.

In the following section we describe the system that we used to generate the tree value conversion standards included in this publication. We also define the circumstances in which those standards fit.

In general, the inputs were regional, and the resulting standards may be applied regionally. But local differences may occur within a region, and changes may take place throughout a region over a period of time. Thus you may want to develop local value standards of your own or adjust our regional ones.

How They Were Calculated

We used the quality index (Q.I.) approach to calculating tree value conversion standards (*Herrick 1956*). This approach was a series of index values to calculate the net value of the 4/4 lumber that can be sawed from the tree's logs. The process is shown in figure 1.

We developed Q.I.'s for individual logs, by species, log grade, and log diameter, using the formula:

$$\begin{aligned}\text{Log Q.I.} = {} & (\%\ \text{FAS} \times \text{P.R.}_{\text{FAS}}) + \\ & (\%\ \text{SEL} \times \text{P.R.}_{\text{SEL}}) \\ & + (\%\ \#1\text{C} \times \text{P.R.}_{\#1\text{C}}) + \ . \ . \ . \\ & + (\%\ \#3\text{B} \times \text{P.R.}_{\#3\text{B}}).\end{aligned}$$

The percentages are the proportion of a log's lumber that would meet the specifications for each lumber grade. We obtained this information by hand-curving data from HARDWOOD LUMBER GRADES FOR STANDARD LUMBER (*Vaughn et al. 1966*).

The P.R.'s are price relatives or price indexes that express the price of each lumber grade as a proportion of that of No. 1 Common (table 1). The price relatives given here are based on the average prices of 4/4 plainsawed No. 1 Common lumber of each species over the 5-year period 1964 through 1968, f.o.b. mills in the Johnson City, Tennessee area, as reported in HARDWOOD MARKET REPORT (*Lemsky 1964-68*).

Table 1. — Lumber Price relatives

Species	Lumber Grade							
	FAS	SEL	SAPS	1C	2C 2A	2B	3A	3B
White ash	1.63	1.56	—	1.00	0.53	—	0.44	0.39
Beech	1.25	1.18	—	1.00	.54	—	.42	.38
Black cherry	1.45	1.40	—	1.00	.46	—	.27	.25
Elm	1.28	1.13	—	1.00	.52	—	—	.40
Hickory	1.19	1.10	—	1.00	.40	—	—	—
Red maple	1.28	1.23	—	1.00	.47	—	.43	.30
Sugar maple	1.53	1.47	—	1.00	.44	—	.38	.27
Black oak[a]	1.65	1.57	—	1.00	.64	—	.56	.37
Chestnut oak[a]	1.82	1.74	—	1.00	.66	—	.58	.39
Red oak	1.65	1.57	—	1.00	.64	—	.56	.37
White oak	1.82	1.74	—	1.00	.66	—	.58	.39
Yellow-poplar	1.42	1.36	1.29	1.00	.67	0.45	.23	.23

[a] Prices for chestnut oak and black oak were not available. Because lumber of these species is intermixed with white oak and red oak respectively, prices of the latter species were used to calculate the price relatives.

We developed tree Q.I.'s for a sample of trees, using the formula:

$$\text{Tree Q.I.} = (\% \text{ of tree volume in 1st log} \times \text{Q.I.}_{\text{1st log}}) + (\% \text{ of tree volume in 2nd log} \times \text{Q.I.}_{\text{2nd log}}) + \ldots + (\% \text{ of tree volume in nth log} \times \text{Q.I.}_{\text{nth log}}).$$

The percentage of tree volume in each log is based on a tree volume table, which provides the volume of each log in a tree of given size as well as the volume for the entire merchantable height of the tree (International ¼-inch log rule).

The log Q.I.'s are those that we developed in the previous step. To apply them, we used a hardwood taper table, which provided the diameter inside bark at the small end of each log.

After developing a quality index for each of our sample trees, we used regression analysis to develop tree quality indexes for each species, by butt-log grade, dbh, and merchantable height. The regression equations and quality index values are given in appendix A.

We then converted these tree quality indexes to gross tree values per thousand board feet. To do so we multiplied each T.Q.I. by the 1972 price of No. 1 Common 4/4 lumber for each species (table 2). The year 1972 was selected because it reflects a period of relative stability in the economy. Prices since that time have been distorted by inflation and recession.

We then converted gross tree values per thousand to net tree values per thousand by subtracting conversion cost — the cost of converting standing timber into 4/4 lumber. It includes the costs of labor and materials used in felling and bucking the trees, skidding and loading, other logging costs, transportation, and milling. In this study we used

Table 2. — Price of No. 1 Common 4/4-inch lumber, January 1, 1972[a]

Species	Price per Mfbm
White ash	$195
Beech	142
Black cherry	175
Elm	145
Hickory	140
Red maple	190
Sugar maple	185
Black oak[b]	155
Chestnut oak[b]	140
Red oak	155
White oak	140
Yellow-poplar	170

[a] Prices from Hardwood Market Report for 4/4 plain-sawed No. 1 Common lumber, f.o.b. mills in the Johnson City, Tennessee area.

[b] Prices for chestnut oak and black oak were not available. Because lumber of these species is intermixed with white oak and red oak respectively, prices of the latter species were used.

an average conversion cost of $70 per thousand for 16-inch trees (table 52).

Finally, we calculated tree value conversion standards by multiplying net tree values per thousand by appropriate tree volumes. We include in appendix A tree value conversion standards by species, butt-log grade, dbh and merchantable height, computed from the lumber prices in table 2 and a conversion cost estimated at $70.

How TVCS's Differ From Stumpage Values

Our tree value conversion standards are not stumpage values: There are some important differences between the two.

The customary method of estimating stumpage value begins with the expected selling price of the product or products that are to be made from the timber. From it is subtracted the estimated cost of converting the timber into those products. The difference is termed a conversion return. And from it is subtracted an allowance for the operator's profit and risk. The final difference, the residue, is the stumpage value of the timber.

Our tree value conversion standards are conversion returns only — one step short of stumpage values. We have refrained from taking that step because profit and risk are somewhat arbitrary, and often highly personal matters.

In computing our tree value conversion standards, we have limited ourselves to a single product — 4/4 lumber. Also, we have used given yields by lumber grade, given lumber prices, and only one level of conversion costs. Our tree value conversion standards are, therefore, estimates of conversion return under a single, specified set of conditions and they must be recognized as such. They are not estimates of conversion return from any particular logging chance. And, since they contain no allowance for profit and risk, they are not stumpage values.

Our tree value conversion standards can, however, be adjusted to fit many local conditions, such as lumber prices, lumber-grade recovery, logging chance, operator efficiency, etc. We will show how this is done in the next section. After making the needed adjustments, you might use the TVCS's to estimate your own stumpage values by subtracting an appropriate allowance for profit and risk.

Adapting TVCS To Local Conditions

Our tree value conversion standards are suitable for regional use and for estimating broad value relationships. But they can also be adapted more closely to local conditions.

Major adjustments are needed where product yields or product values differ greatly from the ones we used in deriving our tree quality indexes. Such cases include local areas where mills a. have different mixes of lumber grade recovery, b. turn part of their output into products other than grade lumber, or c. sell their grade lumber at price mixes other than those we used to derive the price relatives. In such cases we suggest that tree value conversion standards be calculated to fit local or specific circumstances. This can be done by the procedure we outlined for calculating TVCS.

Minor adjustments are needed where our tree quality indexes are suitable, but No. 1 Common lumber prices, conversion costs, or volume measures differ from those we used.

The price of No. 1 Common lumber fluctuates, sometimes for a particular species, sometimes for all species. It may differ from one locality to another, and it may vary from time to time. Conversion costs differ from one logging chance to another for any given operator. So can mill log and lumber overrun and underrun. These kinds of fluctuations and variations are common and it is reasonable to expect them. So we should be able to adjust tree conversion value standards to fit them.

Although such adjustments can be made most efficiently by computer, they can, if necessary, be made with a desk calculator. Either way, they must be made one species at a time; they should be made by log grade, merchantable height, and dbh; and they can be made using the formula

$$\text{TVCS} = [(\text{TQI} \times \text{P\#1C}) - \text{CC}]\ (\text{TV})$$

where

TQI = tree quality index
P#1C = price of No. 1 Common per Mfbm

CC = conversion cost per Mfbm
and TV = tree volume in Mfbm

This formula consolidates some of the steps that we used in deriving our TVCS values. The term TQI x P#1C represents a tree's gross lumber value per Mfbm. That term minus CC represents the tree's net lumber value per Mfbm.

To facilitate making adjustments with a desk calculator, we have included in appendix A a complete set of TQI values, a representative set of conversion costs, and a composite board-foot volume table (International ¼-inch rule). To adjust a tree's TVCS for different prices of No. 1 Common lumber or conversion costs, we need only to insert the tree's TQI and TV values into the formula given above, substitute the appropriate P#1C and CC values and solve the resulting equation. To adjust for overrun or underrun we need, simply, to expand or reduce the tree's value conversion standard by the percentage of overrun or underrun. And, if we need to make adjustments, we can make them by 2-inch diameter classes and interpolate between the classes.

To facilitate making adjustments with a computer, we have included a Fortran IV program in appendix B. This program calculates for each sawtimber tree the TQI, volume, and TVCS, giving the user the option of substituting current prices of No. 1 Common lumber and conversion costs to suit his own situation. The program may be used as presented to summarize the volume and TVCS for the sawtimber component of a particular stand; or the user may wish to incorporate the basic set of equations for volume, TQI, and TVCS into his existing inventory system. The program listing with user instructions and examples is given in appendix B.

How To Use TVCS

As noted earlier, we developed our tree value conversion standards to calculate the rates of value increase and financial maturity diameters for various hardwood species. But TVCS can be put to work in other ways.

Value standards can be applied to forest inventories, much as volume standards are. The mechanics are simple, using either TVCS tables that are comparable to volume tables or TVCS equations that are comparable to volume equations. Such applications add a new dimension to inventory work by allowing stock tables, per-acre estimates, stand summaries, etc. to be expressed in dollars as well as board feet.

TVCS summaries add much meaning to inventories, reflecting timber quality as well as quantity. They can be provided simply by adding value standard calculations to the normal calculations of board-foot volumes. The other ingredients — species, dbh, merchantable height, and butt-log grade — are usually included in field tallies.

There are other possible advantages of including value summaries in inventory systems. One is the ease of making value projections for timber stands, which opens new avenues for evaluating timber management alternatives. An application of such an evaluation is discussed and illustrated in the companion paper AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS (*DeBald and Mendel 1976b*).

SUMMARY

Value is a neglected dimension in timber inventories. There are few prescribed methods of calculating it. Guidelines are few, indefinite, and often sketchily narrative in form. Our presentation of value standards and the method by which they are constructed should overcome these obstacles and encourage others to delve deeper into timber valuation.

The tree value conversion standards are presented in two forms that are familiar to all timber estimators: in volume table format and in volume equation form. Thus they should pose no problem to a potential user. Their resemblance to volume standards is not entirely coincidental. It is an expression of the partial dependence of value on volume. By using value standards we are merely introducing a pricing mechanism into the timber-estimating procedure to produce an estimate of value based on both the volume and quality of the tree.

The availability of value standards and the possibility of altering them to fit local conditions should encourage the reporting of forestry investigations in terms of value as well as volume. Only dbh, merchantable height, and butt-log grade must be measured or estimated. These measurements are already required for most timber inventories, so the standards present an opportunity to enhance the results of forestry investigations without any appreciable increase in cost.

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APPENDIX A

Table 3.—Regression coefficients used to derive tree quality index (TQI) values

Species	Butt-log grade[a]	Regression coefficient b_0	b_1	b_2
White ash	1	0.52016	0.02554	−0.00063
	2	.42017	.02779	− .00153
	3	.19192	.01458	.00666
Beech	1	0.63384	0.01341	−0.00383
	2	.56182	.00840	− .00267
	3	.43325	.00825	− .00169
Black cherry	1	0.62909	0.02316	−0.00319
	2	.41975	.02264	− .00227
	3	.20834	.02347	− .00083
Elm	1	0.70931	0.01151	−0.00430
	2	.51667	.01113	− .00186
	3	.43276	.00797	.00003
Hickory	1	0.57123	0.01550	−0.00476
	2	.51371	.00667	− .00224
	3	.45999	.00000	.00000
Red maple	1	0.54256	0.02047	−0.00535
	2	.70533	.00202	− .00383
	3	.46333	.00008	− .00010
Sugar maple	1	0.59368	0.02170	−0.00616
	2	.43193	.01369	− .00155
	3	.36873	.00952	− .00200
Black oak	1	0.79449	0.01372	−0.00535
	2	.52900	.00994	− .00150
	3	.55305	.00354	− .00157
Chestnut oak	1	0.85192	0.00747	−0.00406
	2	.55315	.00874	− .00181
	3	.46905	.00722	− .00061
Red oak	1	0.69524	0.01869	−0.00418
	2	.59992	.01144	− .00242
	3	.53211	.00574	− .00189
White oak	1	0.56518	0.02548	−0.00464
	2	.33601	.02089	− .00177
	3	.38063	.01206	− .00065
Yellow-poplar	1	0.51132	0.01549	−0.00082
	2	.63478	.00880	− .00344
	3	.41512	.00946	− .00110

where: $TQI = b_0 + b_1 \text{ (dbh)} + b_2 \text{ (merch. height)}$.

[a] For trees with a butt-log grade below 3, we assigned a TQI value of 0.400, a nominal value corresponding to the price relative for lumber grade 3B. Lumber grade yields were not available for such logs. We also labelled them "grade 4". In the hardwood log-grading classification such logs are identified as tie and timber or construction logs. This, in part, explains why the TQI value is constant for all trees with butt-log "grade 4" regardless of species, dbh, or length.

Table 4. — White ash; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.92	$ 11.46	0.91	$ 15.90	0.91	$ 19.29	0.90	$ 22.62	0.90	$ 25.99	0.89	$ 28.56	0.89	$ 30.46
17	.94	13.72	.94	19.14	.93	23.78	.93	27.77	.92	31.58	.92	34.98	.91	37.54
18	.97	16.66	.96	23.02	.96	28.55	.95	33.50	.95	38.24	.94	42.67	.94	47.02
19	1.00	19.85	.99	27.48	.99	34.09	.98	40.08	.98	45.60	.97	50.90	.97	56.11
20	1.02	23.42	1.02	32.28	1.01	40.05	1.01	47.18	1.00	53.52	1.00	59.77	.99	65.92
21	1.05	27.38	1.04	37.70	1.04	46.88	1.03	55.35	1.03	63.43	1.02	70.68	1.02	76.44
22	1.07	31.77	1.07	43.80	1.06	54.32	1.06	64.11	1.05	73.31	1.05	81.65	1.04	89.14
23	1.10	36.30	1.09	50.00	1.09	62.27	1.08	73.44	1.08	83.85	1.07	94.12	1.07	104.25
24	1.12	41.70	1.12	56.92	1.11	70.32	1.11	82.90	1.10	96.13	1.10	107.59	1.09	118.10
25	1.15	47.11	1.14	64.05	1.14	79.60	1.13	93.45	1.13	107.97	1.12	121.48	1.12	134.00
26	1.17	53.01	1.17	72.05	1.16	89.12	1.16	105.12	1.15	120.94	1.15	135.71	1.14	150.31
27	1.20	59.11	1.19	79.60	1.19	98.95	1.18	116.31	1.18	135.24	1.17	150.42	1.17	167.19
28	1.23	65.06	1.22	89.27	1.22	110.07	1.21	128.81	1.21	148.26	1.20	167.49	1.19	184.69
29	1.25	72.59	1.25	98.40	1.24	121.65	1.24	143.71	1.23	163.66	1.23	185.26	1.22	204.76
30	1.28	80.80	1.27	107.85	1.27	133.65	1.26	157.24	1.26	179.62	1.25	203.69	1.25	225.59
31	1.30	88.93	1.30	119.67	1.29	148.11	1.29	173.27	1.28	198.18	1.28	224.81	1.27	247.23
32	1.33	97.36	1.32	130.91	1.32	162.09	1.31	189.90	1.31	217.44	1.30	244.70	1.30	271.69
33	1.35	106.09	1.35	143.61	1.34	176.58	1.34	207.13	1.33	237.40	1.33	267.37	1.32	297.04
34	1.38	115.12	1.37	156.76	1.37	193.72	1.36	227.11	1.36	258.06	1.35	292.96	1.35	323.30
35	1.40	125.56	1.40	170.37	1.39	209.26	1.39	245.60	1.38	281.61	1.38	317.29	1.37	352.63

Table 5. — White ash; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.78	$ 6.22	0.77	$ 8.39	0.76	$ 10.35	0.75	$ 11.66	0.74	$ 12.72	—	—	—	—
15	.81	7.94	.80	10.74	.79	13.04	.78	14.87	.76	16.42	0.75	$ 17.25	—	—
16	.84	9.86	.83	13.45	.82	16.04	.80	18.47	.79	20.83	.78	22.45	.77	$ 23.47
17	.87	11.97	.86	16.45	.84	20.11	.83	23.10	.82	25.83	.81	28.11	.79	29.63
18	.90	14.72	.88	20.05	.87	24.50	.86	28.32	.85	31.84	.83	34.96	.82	37.88
19	.92	17.73	.91	24.22	.90	29.64	.89	34.37	.87	38.55	.86	42.40	.85	46.04
20	.95	21.12	.94	28.75	.93	35.23	.91	40.97	.90	45.87	.89	50.52	.88	54.94
21	.98	24.91	.97	33.90	.95	41.66	.94	48.61	.93	55.01	.92	60.53	.91	64.61
22	1.01	29.13	.99	39.73	.98	48.73	.97	56.85	.96	64.27	.95	70.73	.93	76.29
23	1.03	33.52	1.02	45.70	1.01	56.32	1.00	65.72	.99	74.22	.97	82.39	.96	90.22
24	1.06	38.74	1.05	52.36	1.04	64.05	1.03	74.74	1.01	85.78	1.00	94.99	.99	103.15
25	1.09	44.00	1.08	59.26	1.07	72.95	1.05	84.82	1.04	97.03	1.03	108.08	1.02	117.99
26	1.12	49.74	1.11	67.00	1.09	82.13	1.08	95.98	1.07	109.38	1.06	121.56	1.04	133.31
27	1.15	55.71	1.13	74.38	1.12	91.66	1.11	106.77	1.10	123.03	1.08	135.57	1.07	149.25
28	1.17	61.58	1.16	83.79	1.15	102.44	1.14	118.85	1.12	135.59	1.11	151.81	1.10	165.87
29	1.20	68.97	1.19	92.74	1.18	113.72	1.16	133.23	1.15	150.44	1.14	168.82	1.13	184.96
30	1.23	77.05	1.22	102.05	1.20	125.46	1.19	146.42	1.18	165.90	1.17	186.56	1.16	204.86
31	1.26	85.10	1.24	113.66	1.23	139.59	1.22	162.04	1.21	183.86	1.20	206.88	1.18	225.65
32	1.28	93.47	1.27	124.77	1.26	153.34	1.25	178.30	1.24	202.59	1.22	226.20	1.21	249.15
33	1.31	102.17	1.30	137.33	1.29	167.64	1.28	195.22	1.26	222.07	1.25	248.21	1.24	273.64
34	1.34	111.20	1.33	150.39	1.32	184.54	1.30	214.82	1.29	242.33	1.28	273.08	1.27	299.11
35	1.37	121.64	1.36	163.93	1.34	199.99	1.33	233.10	1.32	265.40	1.31	296.89	1.29	327.57

Table 6. — White ash; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.46	$ 0.41	0.51	$ 1.29	—	—	—	—	—	—	—	—	—	—
12	.47	.78	.53	1.92	0.58	$ 3.44	—	—	—	—	—	—	—	—
13	.49	1.27	.54	2.79	.59	4.65	0.65	$ 6.68	—	—	—	—	—	—
14	.50	1.87	.56	3.75	.61	6.22	.66	8.94	0.72	$ 12.00	—	—	—	—
15	.52	2.64	.57	5.00	.62	7.91	.68	11.25	.73	15.03	0.78	$ 18.71	—	—
16	.53	3.54	.59	6.48	.64	9.81	.69	13.82	.74	18.59	.80	23.47	0.85	$ 28.33
17	.55	4.57	.60	8.15	.65	12.37	.71	17.12	.76	22.55	.81	28.47	.87	34.35
18	.56	5.90	.61	10.17	.67	15.15	.72	20.82	.77	27.29	.83	34.44	.88	42.42
19	.58	7.41	.63	12.53	.68	18.42	.74	25.09	.79	32.50	.84	40.77	.90	49.98
20	.59	9.14	.64	15.13	.70	21.98	.75	29.72	.80	38.12	.86	47.56	.91	58.04
21	.60	11.10	.66	18.11	.71	26.08	.76	35.06	.82	45.13	.87	55.90	.92	66.59
22	.62	13.32	.67	21.50	.73	30.60	.78	40.82	.83	52.13	.89	64.21	.94	76.91
23	.63	15.69	.69	25.02	.74	35.47	.79	46.98	.85	59.59	.90	73.65	.95	89.17
24	.65	18.38	.70	28.83	.75	40.30	.81	53.09	.86	68.13	.91	83.67	.97	100.10
25	.66	21.07	.72	32.72	.77	45.78	.82	59.83	.88	76.23	.93	93.86	.98	112.56
26	.68	23.96	.73	37.01	.78	51.33	.84	67.18	.89	85.00	.94	104.14	1.00	125.15
27	.69	26.95	.75	41.06	.80	57.03	.85	74.16	.91	94.60	.96	114.64	1.01	137.99
28	.71	29.88	.76	46.20	.81	63.45	.87	81.92	.92	103.21	.97	126.78	1.03	151.16
29	.72	33.57	.77	51.08	.83	70.13	.88	91.18	.93	113.41	.99	139.34	1.04	166.26
30	.74	37.60	.79	56.15	.84	77.05	.90	99.52	.95	123.93	1.00	152.26	1.06	181.76
31	.75	41.62	.80	62.47	.86	85.38	.91	109.42	.96	136.16	1.02	167.06	1.07	197.74
32	.77	45.82	.82	68.51	.87	93.43	.92	119.66	.98	148.78	1.03	180.82	1.08	215.77
33	.78	50.19	.83	75.33	.89	101.78	.94	130.24	.99	161.82	1.05	196.51	1.10	234.32
34	.79	54.74	.85	82.41	.90	111.65	.95	142.51	1.01	175.25	1.06	214.21	1.11	253.39
35	.81	59.99	.86	89.75	.92	120.60	.97	153.82	1.02	190.57	1.08	230.86	1.13	274.67

Table 7. — White ash; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$ —.14	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	—.04	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	.10	.40	$ 0.14	.40	$ 0.18	.40	$ 0.20	.40	—	.40	—	.40	—
14	.40	.29	.40	.40	.40	.51	.40	.60	.40	$ 0.67	.40	—	.40	—
15	.40	.54	.40	.75	.40	.93	.40	1.10	.40	1.25	.40	$ 1.35	.40	—
16	.40	.84	.40	1.18	.40	1.44	.40	1.70	.40	1.98	.40	2.19	.40	$ 2.36
17	.40	1.20	.40	1.69	.40	2.12	.40	2.49	.40	2.86	.40	3.19	.40	3.46
18	.40	1.66	.40	2.32	.40	2.90	.40	3.43	.40	3.95	.40	4.44	.40	4.93
19	.40	2.20	.40	3.07	.40	3.84	.40	4.55	.40	5.22	.40	5.87	.40	6.52
20	.40	2.83	.40	3.93	.40	4.92	.40	5.83	.40	6.67	.40	7.50	.40	8.33
21	.40	3.56	.40	4.93	.40	6.18	.40	7.34	.40	8.47	.40	9.51	.40	10.36
22	.40	4.39	.40	6.09	.40	7.60	.40	9.03	.40	10.39	.40	11.65	.40	12.81
23	.40	5.29	.40	7.33	.40	9.19	.40	10.90	.40	12.53	.40	14.15	.40	15.78
24	.40	6.17	.40	8.48	.40	10.53	.40	12.49	.40	14.58	.40	16.41	.40	18.13
25	.40	6.97	.40	9.53	.40	11.91	.40	14.07	.40	16.35	.40	18.51	.40	20.53
26	.40	7.72	.40	10.56	.40	13.13	.40	15.58	.40	18.02	.40	20.34	.40	22.66
27	.40	8.43	.40	11.42	.40	14.27	.40	16.87	.40	19.72	.40	22.06	.40	24.65
28	.40	9.07	.40	12.50	.40	15.50	.40	18.23	.40	21.10	.40	23.97	.40	26.57
29	.40	9.88	.40	13.47	.40	16.74	.40	19.87	.40	22.75	.40	25.89	.40	28.76
30	.40	10.74	.40	14.41	.40	17.95	.40	21.22	.40	24.37	.40	27.77	.40	30.92
31	.40	11.55	.40	15.62	.40	19.43	.40	22.85	.40	26.26	.40	29.94	.40	33.09
32	.40	12.37	.40	16.71	.40	20.78	.40	24.47	.40	28.15	.40	31.84	.40	35.52
33	.40	13.18	.40	17.92	.40	22.14	.40	26.10	.40	30.05	.40	34.00	.40	37.96
34	.40	14.00	.40	19.15	.40	23.77	.40	27.99	.40	31.96	.40	36.45	.40	40.41
35	.40	14.95	.40	20.37	.40	25.14	.40	29.64	.40	34.13	.40	38.63	.40	43.13

Table 8. — Beech; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.79	$ 4.39	0.76	$ 5.50	0.73	$ 5.95	0.70	$ 6.12	0.66	—	0.63	—	0.60	—
17	.80	5.41	.77	6.89	.74	7.73	.71	8.03	.68	—	.65	—	.62	—
18	.81	6.74	.78	8.57	.75	9.68	.74	10.25	.69	$ 10.40	.66	—	.63	—
19	.83	8.21	.80	10.52	.77	12.00	.74	12.85	.70	13.17	.67	—	.64	—
20	.84	9.87	.81	12.68	.78	14.56	.75	15.75	.72	16.26	.69	$ 16.34	.66	—
21	.85	11.74	.82	15.14	.79	17.52	.76	19.14	.73	20.12	.70	20.39	.67	—
22	.87	13.84	.84	17.94	.81	20.81	.78	22.85	.75	24.15	.71	24.67	.68	—
23	.88	16.03	.85	20.84	.82	24.39	.79	26.91	.76	28.57	.73	29.62	.70	$ 30.06
24	.89	18.52	.86	23.93	.83	27.87	.80	30.83	.77	33.38	.74	34.68	.71	35.08
25	.91	20.97	.88	27.04	.85	31.75	.82	35.08	.79	37.96	.75	39.79	.72	40.63
26	.92	23.57	.89	30.43	.86	35.63	.83	39.64	.80	42.81	.77	44.88	.74	46.17
27	.93	26.22	.90	33.58	.87	39.58	.84	43.95	.81	48.08	.78	50.08	.75	51.84
28	.95	28.77	.92	37.60	.89	44.01	.86	48.74	.83	52.87	.79	56.05	.76	57.70
29	.96	32.01	.93	41.37	.90	48.63	.87	54.44	.84	58.53	.81	62.30	.78	64.43
30	.97	35.52	.94	45.26	.91	53.38	.88	59.60	.85	61.38	.82	68.77	.79	71.42
31	.99	38.98	.96	50.13	.93	59.12	.90	65.72	.87	71.19	.84	76.20	.80	78.74
32	1.00	42.56	.97	54.74	.94	64.66	.91	72.07	.88	78.27	.85	83.25	.82	87.00
33	1.02	46.25	.98	59.95	.95	70.40	.92	78.66	.89	85.62	.86	91.27	.83	95.62
34	1.03	50.06	1.00	65.33	.97	77.18	.94	86.29	.91	93.24	.88	100.34	.84	104.59
35	1.04	54.47	1.01	70.89	.98	83.33	.95	93.37	.92	101.93	.89	109.01	.86	114.61

Table 9. — Beech; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.64	$ 1.27	0.62	$ 1.14	0.59	—	0.57	—	0.55	—	—	—	—	—
15	.65	1.79	.62	2.10	.60	$ 2.14	.58	—	.56	—	0.54	—	—	—
16	.65	2.39	.63	2.91	.61	3.02	.59	—	.57	—	.55	—	0.53	—
17	.66	3.09	.64	3.84	.62	4.18	.60	$ 4.19	.58	—	.56	—	.53	—
18	.67	3.99	.65	4.98	.63	5.52	.61	5.68	.59	—	.56	—	.54	—
19	.68	5.00	.66	6.33	.64	7.11	.61	7.47	.59	$ 7.18	.57	—	.55	—
20	.69	6.16	.67	7.84	.64	8.91	.62	9.51	.60	9.66	.58	—	.56	—
21	.70	7.49	.67	9.58	.65	11.00	.63	11.90	.61	12.37	.59	—	.57	—
22	.70	8.98	.68	11.58	.66	13.36	.64	14.57	.62	15.27	.60	$ 15.44	.58	—
23	.71	10.57	.69	13.69	.67	15.96	.65	17.52	.63	18.49	.61	19.04	.58	$ 19.17
24	.72	12.31	.70	15.86	.68	18.10	.66	20.28	.64	21.86	.61	22.59	.59	22.71
25	.73	14.00	.71	18.00	.69	21.07	.67	23.21	.64	25.02	.62	26.10	.60	26.51
26	.74	15.75	.72	20.28	.69	23.68	.67	26.26	.65	28.26	.63	29.51	.61	30.20
27	.75	17.51	.72	22.38	.70	26.30	.68	29.12	.66	31.74	.64	32.93	.62	33.93
28	.75	19.20	.73	25.03	.71	29.23	.69	32.26	.67	34.88	.65	36.83	.63	37.75
29	.76	21.34	.74	27.52	.72	32.26	.70	36.01	.68	38.59	.66	40.91	.63	42.13
30	.77	23.66	.75	30.08	.73	35.38	.71	39.39	.69	42.41	.66	45.12	.64	46.66
31	.78	25.94	.76	33.28	.74	39.15	.72	43.39	.69	46.85	.67	49.96	.65	51.40
32	.79	28.30	.77	36.31	.75	42.78	.72	47.54	.70	51.46	.68	54.53	.66	56.75
33	.80	30.72	.78	39.73	.75	46.53	.73	51.84	.71	56.24	.69	59.74	.67	62.33
34	.80	33.23	.78	43.26	.76	50.97	.74	56.82	.72	61.20	.70	65.62	.68	68.12
35	.81	36.12	.79	46.90	.77	54.98	.75	61.43	.73	66.85	.71	71.24	.69	74.60

Table 10. — Beech; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.50	$ —0.49	0.48	—	—	—	—	—	—	—	—	—	—	—
12	.51	—.40	.49	—	0.48	—	—	—	—	—	—	—	—	—
13	.51	—.24	.50	—	.49	—	0.47	—	—	—	—	—	—	—
14	.52	—.02	.51	—	.49	—	.48	—	0.47	—	—	—	—	—
15	.53	.28	.52	—	.50	—	.49	—	.48	—	0.47	—	—	—
16	.54	.67	.52	—	.51	—	.50	—	.48	—	.47	—	0.46	—
17	.55	1.15	.53	$ 1.30	.52	—	.51	—	.49	—	.48	—	.47	—
18	.55	1.77	.54	2.10	.53	$ 2.17	.51	—	.50	—	.49	—	.47	—
19	.56	2.50	.55	3.08	.54	3.33	.52	$ 3.35	.51	—	.50	—	.48	—
20	.57	3.36	.56	4.21	.54	4.70	.53	4.90	.52	—	.50	—	.49	—
21	.58	4.37	.57	5.55	.55	6.32	.54	6.76	.53	$ 6.93	.51	—	.50	—
22	.59	5.53	.57	7.11	.56	8.18	.55	8.89	.53	9.28	.52	$ 9.34	.51	—
23	.60	6.80	.58	8.81	.57	10.28	.56	11.30	.54	11.95	.53	12.32	.51	$ 12.43
24	.60	8.14	.59	10.51	.58	12.23	.56	13.52	.55	14.63	.54	15.19	.52	15.35
25	.61	9.43	.60	12.18	.59	14.32	.57	15.84	.56	17.17	.54	18.02	.53	18.44
26	.62	10.76	.61	13.92	.59	16.34	.58	18.22	.57	19.73	.55	20.75	.54	21.42
27	.63	12.11	.62	15.54	.60	18.37	.59	20.46	.57	22.46	.56	23.49	.55	24.43
28	.64	13.41	.62	17.57	.61	20.63	.60	22.93	.58	24.97	.57	26.59	.56	27.52
29	.65	15.04	.63	19.50	.62	23.01	.60	25.86	.59	27.93	.58	29.88	.56	31.08
30	.65	16.82	.64	21.50	.63	25.46	.61	28.55	.60	30.99	.59	33.28	.57	34.78
31	.66	18.59	.65	23.99	.63	28.42	.62	31.73	.61	34.55	.59	37.20	.58	38.69
32	.67	20.43	.66	26.38	.64	31.30	.63	35.06	.62	38.28	.60	40.96	.59	43.10
33	.68	22.34	.66	29.08	.65	34.31	.64	38.53	.62	42.17	.61	45.24	.60	47.73
34	.69	24.33	.67	31.89	.66	37.86	.65	42.55	.63	46.24	.62	50.08	.61	52.59
35	.69	26.63	.68	34.81	.67	41.12	.65	46.32	.64	50.87	.63	54.77	.61	58.01

Table 11. — Beech; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$ −1.15	0.40	—	0.40	—	0.40	—	0.40	—	.40	—	.40	—
12	.40	−1.25	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	−1.34	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	−1.39	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	−1.41	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	−1.39	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	−1.30	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	−1.20	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	−1.02	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	− .77	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
21	.40	− .45	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
22	.40	− .04	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
23	.40	.46	.40	$ 0.63	.40	$ 0.79	.40	$ 0.94	.40	$ 1.08	.40	$ 1.22	.40	$ 1.36
24	.40	.83	.40	1.14	.40	1.42	.40	1.68	.40	1.96	.40	2.21	.40	2.44
25	.40	1.14	.40	1.56	.40	1.95	.40	2.30	.40	2.68	.40	3.03	.40	3.36
26	.40	1.36	.40	1.87	.40	2.32	.40	2.75	.40	3.18	.40	3.59	.40	4.00
27	.40	1.54	.40	2.09	.40	2.61	.40	3.09	.40	3.61	.40	4.04	.40	4.51
28	.40	1.69	.40	2.33	.40	2.89	.40	3.39	.40	3.93	.40	4.46	.40	4.95
29	.40	1.87	.40	2.55	.40	3.17	.40	3.76	.40	4.31	.40	4.90	.40	5.44
30	.40	2.05	.40	2.75	.40	3.42	.40	4.05	.40	4.65	.40	5.30	.40	5.90
31	.40	2.23	.40	3.01	.40	3.74	.40	4.40	.40	5.06	.40	5.77	.40	6.38
32	.40	2.40	.40	3.24	.40	4.04	.40	4.75	.40	5.17	.40	6.18	.40	6.90
33	.40	2.58	.40	3.51	.40	4.33	.40	5.11	.40	5.88	.40	6.66	.40	7.43
34	.40	2.76	.40	3.78	.40	4.69	.40	5.52	.40	6.30	.40	7.19	.40	7.97
35	.40	2.97	.40	4.05	.40	5.00	.40	5.89	.40	6.78	.40	7.68	.40	8.57

Table 12. — Black cherry; butt log grade 1

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.95	**$ 10.08**	0.92	**$ 13.45**	0.90	**$ 15.67**	0.87	**$ 17.59**	0.85	**$ 19.30**	0.82	**$ 20.18**	0.80	**$ 20.41**
17	.97	**12.06**	.95	**16.23**	.92	**19.40**	.90	**21.76**	.87	**23.70**	.84	**25.08**	.82	**25.64**
18	.99	**14.64**	.97	**19.55**	.94	**23.38**	.92	**26.42**	.89	**28.98**	.87	**31.00**	.84	**32.65**
19	1.02	**17.43**	.99	**23.36**	.97	**28.02**	.94	**31.79**	.92	**34.84**	.89	**37.39**	.86	**39.54**
20	1.04	**20.55**	1.02	**27.47**	.99	**33.02**	.96	**37.62**	.94	**41.20**	.91	**44.35**	.89	**47.04**
21	1.06	**24.02**	1.04	**32.13**	1.01	**38.75**	.99	**44.34**	.96	**49.15**	.94	**52.90**	.91	**55.16**
22	1.09	**27.86**	1.06	**37.36**	1.04	**45.02**	1.01	**51.56**	.99	**57.15**	.96	**61.59**	.93	**64.97**
23	1.11	**31.82**	1.09	**42.69**	1.06	**51.73**	1.03	**59.30**	1.01	**65.72**	.98	**71.51**	.96	**76.68**
24	1.13	**36.52**	1.11	**48.59**	1.08	**58.47**	1.06	**67.07**	1.03	**75.59**	1.01	**82.13**	.98	**87.41**
25	1.16	**41.20**	1.13	**54.65**	1.11	**66.21**	1.08	**75.71**	1.05	**85.11**	1.03	**93.06**	1.00	**99.65**
26	1.18	**46.28**	1.15	**61.42**	1.13	**74.12**	1.10	**85.23**	1.08	**95.48**	1.05	**104.23**	1.03	**112.18**
27	1.20	**51.52**	1.18	**67.78**	1.15	**82.27**	1.13	**94.33**	1.10	**106.90**	1.08	**115.76**	1.05	**125.14**
28	1.23	**56.61**	1.20	**75.94**	1.18	**91.47**	1.15	**104.49**	1.12	**117.29**	1.10	**129.11**	1.07	**138.59**
29	1.25	**63.06**	1.22	**83.61**	1.20	**101.05**	1.17	**116.60**	1.15	**129.60**	1.12	**143.05**	1.10	**154.03**
30	1.27	**70.08**	1.25	**91.55**	1.22	**110.97**	1.20	**127.60**	1.17	**142.35**	1.15	**157.51**	1.12	**170.07**
31	1.30	**77.02**	1.27	**101.49**	1.24	**122.92**	1.22	**140.63**	1.19	**157.17**	1.17	**174.09**	1.14	**186.79**
32	1.32	**84.20**	1.29	**110.92**	1.27	**134.46**	1.24	**154.14**	1.22	**172.57**	1.19	**189.74**	1.17	**205.67**
33	1.34	**91.62**	1.32	**121.57**	1.29	**146.42**	1.27	**168.15**	1.24	**188.53**	1.21	**207.58**	1.19	**225.28**
34	1.37	**99.29**	1.34	**132.59**	1.31	**160.57**	1.29	**184.38**	1.26	**205.07**	1.24	**227.72**	1.21	**245.64**
35	1.39	**108.17**	1.36	**143.97**	1.34	**173.39**	1.31	**199.41**	1.29	**223.92**	1.26	**246.91**	1.24	**268.38**

Table 13. — Black cherry; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.70	$ 3.81	0.68	$ 4.96	0.66	$ 5.86	0.65	$ 6.31	0.63	$ 6.54	—	—	—	—
15	.72	5.00	.70	6.55	.69	7.68	.67	8.43	.65	8.92	0.63	$ 8.93	—	—
16	.75	6.35	.73	8.43	.71	9.75	.69	10.86	.67	11.81	.65	12.23	0.64	$ 12.23
17	.77	7.86	.75	10.53	.73	12.54	.71	13.99	.70	15.15	.68	15.94	.66	16.18
18	.79	9.82	.77	13.08	.75	15.60	.74	17.58	.72	19.21	.70	20.47	.68	21.48
19	.81	11.99	.80	16.05	.78	19.22	.76	21.78	.74	23.82	.72	25.52	.70	26.92
20	.84	14.45	.82	19.31	.80	23.20	.78	26.42	.76	28.92	.75	31.11	.73	32.98
21	.86	17.22	.84	23.04	.82	27.81	.80	31.83	.79	35.29	.77	38.00	.75	39.65
22	.88	20.33	.86	27.28	.85	32.91	.83	37.73	.81	41.86	.79	45.17	.77	47.71
23	.90	23.58	.89	31.68	.87	38.44	.85	44.13	.83	48.99	.81	53.40	.80	57.37
24	.93	27.39	.91	36.50	.89	44.00	.87	50.57	.85	57.11	.84	62.18	.82	66.33
25	.95	31.21	.93	41.48	.91	50.36	.89	57.70	.88	65.01	.86	71.26	.84	76.50
26	.97	35.36	.95	47.02	.94	56.87	.92	65.54	.90	73.61	.88	80.57	.86	86.95
27	.99	39.65	.98	52.29	.96	63.62	.94	73.12	.92	83.08	.90	90.22	.89	97.82
28	1.02	43.87	1.00	58.99	.98	71.24	.96	81.59	.94	91.84	.93	101.39	.91	109.17
29	1.04	49.19	1.02	65.39	1.00	79.22	.99	91.67	.97	102.17	.95	113.12	.93	122.20
30	1.06	55.00	1.04	72.03	1.03	87.54	1.01	100.95	.99	112.95	.97	125.37	.95	135.82
31	1.09	60.79	1.07	80.32	1.05	97.55	1.03	111.92	1.01	125.47	.99	139.42	.98	150.10
32	1.11	66.82	1.09	88.27	1.07	107.31	1.05	123.37	1.04	138.55	1.02	152.83	1.00	166.23
33	1.13	73.10	1.11	97.25	1.09	117.47	1.08	135.30	1.06	152.18	1.04	168.11	1.02	183.09
34	1.15	79.61	1.13	106.60	1.12	129.47	1.10	149.12	1.08	166.38	1.06	185.38	1.04	200.67
35	1.18	87.13	1.16	116.30	1.14	140.47	1.12	162.05	1.10	182.56	1.09	201.98	1.07	220.33

Table 14. — Black cherry; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.45	$—0.07	0.45	—	—	—	—	—	—	—	—	—	—	—
12	.48	.27	.47	$ 0.29	0.46	—	—	—	—	—	—	—	—	—
13	.50	.75	.49	.95	.49	$ 1.02	0.48	—	—	—	—	—	—	—
14	.52	1.37	.52	1.77	.51	2.09	.50	$ 2.25	0.50	$ 2.32	—	—	—	—
15	.55	2.17	.54	2.87	.53	3.40	.53	3.77	.52	4.04	0.51	$ 4.11	—	—
16	.57	3.13	.56	4.21	.56	4.95	.55	5.61	.54	6.22	.54	6.57	0.53	$ 6.73
17	.59	4.26	.59	5.80	.58	7.03	.57	7.99	.57	8.83	.56	9.51	.55	9.90
18	.62	5.72	.61	7.75	.60	9.41	.60	10.81	.59	12.07	.58	13.15	.58	14.15
19	.64	7.40	.63	10.07	.63	12.27	.62	14.18	.61	15.83	.61	17.34	.60	18.74
20	.66	9.34	.66	12.69	.63	15.52	.64	18.00	.64	20.10	.63	22.09	.62	23.96
21	.69	11.57	.68	15.73	.67	19.31	.67	22.50	.66	25.44	.65	27.96	.65	29.81
22	.71	14.10	.70	19.23	.70	23.58	.69	27.51	.68	31.09	.68	34.21	.67	36.89
23	.73	16.82	.73	22.95	.72	28.29	.71	33.03	.71	37.32	.70	41.45	.69	45.41
24	.76	19.96	.75	27.00	.74	33.05	.74	38.60	.73	44.34	.72	49.14	.72	53.42
25	.78	23.14	.78	31.20	.77	38.45	.76	44.76	.75	51.26	.75	57.16	.74	62.48
26	.81	26.60	.80	35.87	.79	44.02	.79	51.52	.78	58.79	.77	65.42	.77	71.85
27	.83	30.21	.82	40.39	.82	49.84	.81	58.15	.80	67.10	.80	74.05	.79	81.66
28	.85	33.81	.85	46.08	.84	56.42	.83	65.56	.83	74.92	.82	84.02	.81	91.96
29	.88	38.32	.87	51.61	.86	63.38	.86	74.38	.85	84.13	.84	94.58	.84	103.80
30	.90	43.27	.89	57.40	.89	70.69	.88	82.64	.87	93.80	.87	105.67	.86	116.26
31	.92	48.27	.92	64.57	.91	79.45	.90	92.39	.90	105.03	.89	118.40	.88	129.39
32	.95	53.51	.94	71.56	.93	88.10	.93	102.63	.92	116.83	.91	130.70	.91	144.24
33	.97	59.00	.96	79.45	.96	97.17	.95	113.36	.94	129.21	.94	144.70	.93	159.85
34	.99	64.75	.99	87.72	.98	107.85	.97	125.78	.97	142.17	.96	160.53	.95	176.20
35	1.02	71.37	1.01	96.37	1.00	117.79	1.00	137.56	.99	156.93	.98	175.91	.98	194.49

Table 15. — Black cherry; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−0.51	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	− .48	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	− .43	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	− .32	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	− .18	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	.02	.40	$ 0.03	.40	$ 0.03	.40	$ 0.01	.40	$ 0.01	.40	$ 0.05	.40	$ 0.05
17	.40	.28	.40	.39	.40	.49	.40	.57	.40	.65	.40	.73	.40	.79
18	.40	.60	.40	.84	.40	1.05	.40	1.24	.40	1.43	.40	1.61	.40	1.78
19	.40	1.01	.40	1.10	.40	1.76	.40	2.08	.40	2.38	.40	2.68	.40	2.98
20	.40	1.49	.40	2.07	.40	2.59	.40	3.07	.40	3.51	.40	3.94	.40	4.38
21	.40	2.06	.40	2.86	.40	3.58	.40	4.26	.40	4.91	.40	5.51	.40	6.00
22	.40	2.73	.40	3.79	.40	4.73	.40	5.62	.40	6.46	.40	7.25	.40	7.96
23	.40	3.48	.40	4.82	.40	6.04	.40	7.16	.40	8.23	.40	9.29	.40	10.36
24	.40	4.17	.40	5.72	.40	7.11	.40	8.43	.40	9.83	.40	11.07	.40	12.22
25	.40	4.77	.40	6.53	.40	8.16	.40	9.63	.40	11.19	.40	12.66	.40	14.05
26	.40	5.32	.40	7.27	.40	9.04	.40	10.73	.40	12.41	.40	14.00	.40	15.60
27	.40	5.82	.40	7.88	.40	9.85	.40	11.64	.40	13.61	.40	15.22	.40	17.01
28	.40	6.26	.40	8.64	.40	10.71	.40	12.59	.40	14.57	.40	16.55	.40	18.34
29	.40	6.83	.40	9.31	.40	11.57	.40	13.73	.40	15.72	.40	17.89	.40	19.87
30	.40	7.43	.40	9.96	.40	12.40	.40	14.66	.40	16.83	.40	19.18	.40	21.35
31	.40	7.99	.40	10.80	.40	13.43	.40	15.78	.40	18.14	.40	20.68	.40	22.85
32	.40	8.55	.40	11.54	.40	14.36	.40	16.90	.40	19.44	.40	21.98	.40	24.52
33	.40	9.11	.40	12.38	.40	15.29	.40	18.02	.40	20.75	.40	23.47	.40	26.20
34	.40	9.67	.40	13.22	.40	16.41	.40	19.33	.40	22.06	.40	25.15	.40	27.88
35	.40	10.32	.40	14.07	.40	17.35	.40	20.45	.40	23.56	.40	26.66	.40	29.75

Table 16. — Elm; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.82	$ 5.21	0.79	$ 6.56	0.76	$ 7.13	0.72	$ 7.37	0.69	—	0.65	—	0.62	—
17	.84	6.30	.80	8.04	.77	9.04	.73	9.42	.70	—	.66	—	.63	—
18	.85	7.73	.81	9.83	.78	11.11	.74	11.76	.71	$ 11.94	.68	—	.64	—
19	.86	9.29	.82	11.89	.79	13.55	.76	14.48	.72	14.81	.69	—	.65	—
20	.87	11.04	.84	14.15	.80	16.21	.77	17.49	.73	17.99	.70	$ 18.00	.66	—
21	.88	13.00	.85	16.71	.81	19.28	.78	20.98	.74	21.96	.71	22.13	.68	—
22	.89	15.17	.86	19.61	.83	22.67	.79	24.78	.76	26.06	.72	26.45	.69	—
23	.91	17.44	.87	22.59	.84	26.33	.80	28.91	.77	30.52	.73	31.43	.70	$ 31.65
24	.92	20.02	.88	25.76	.85	29.87	.81	32.88	.78	35.40	.74	36.52	.71	36.64
25	.93	22.54	.89	28.94	.86	33.83	.83	37.18	.79	40.00	.76	41.63	.72	42.15
26	.94	25.21	.91	32.41	.87	37.77	.84	41.79	.80	44.86	.77	46.68	.73	47.61
27	.95	27.92	.92	35.60	.88	41.76	.85	46.11	.81	50.12	.78	51.82	.74	53.17
28	.96	30.51	.93	39.69	.89	46.23	.86	50.89	.83	54.85	.79	57.71	.76	58.90
29	.97	33.81	.94	43.49	.91	50.86	.87	56.60	.84	60.45	.80	63.85	.77	65.46
30	.99	37.38	.95	47.40	.92	55.61	.88	61.72	.85	66.22	.81	70.19	.78	72.25
31	1.00	40.87	.96	52.30	.93	61.36	.89	67.80	.86	72.94	.83	77.46	.79	79.33
32	1.01	44.47	.97	56.91	.94	66.86	.91	74.07	.87	79.88	.84	84.30	.80	87.32
33	1.02	48.17	.99	62.11	.95	72.54	.92	80.55	.88	87.07	.85	92.09	.81	95.61
34	1.03	51.97	1.00	67.47	.96	79.27	.93	88.07	.89	94.50	.86	100.89	.83	104.22
35	1.04	56.37	1.01	72.98	.97	85.30	.94	94.98	.91	102.96	.87	109.25	.84	113.84

Table 17. — Elm; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.64	$ 1.49	0.63	$ 1.84	0.61	$ 2.04	0.60	—	0.58	—	—	—	—	—
15	.65	2.08	.64	2.62	.62	2.94	.61	$ 3.05	.59	—	0.58	—	—	—
16	.67	2.78	.65	3.57	.64	3.98	.62	4.26	.61	$ 4.40	.59	—	0.58	—
17	.68	3.57	.66	4.66	.65	5.39	.63	5.82	.62	6.07	.69	$ 6.11	.59	—
18	.69	4.59	.67	5.99	.66	6.98	.64	7.66	.63	8.12	.61	8.37	.60	$ 8.43
19	.70	5.74	.68	7.55	.67	8.87	.65	9.84	.64	10.50	.62	10.94	.61	11.19
20	.71	7.07	.69	9.30	.68	10.99	.67	12.29	.65	13.18	.64	13.86	.62	14.33
21	.72	8.57	.71	11.32	.69	13.46	.68	15.16	.66	16.53	.65	17.46	.63	17.83
22	.73	10.27	.72	13.62	.70	16.22	.69	18.35	.67	20.06	.66	21.29	.64	22.09
23	.74	12.07	.73	16.05	.71	19.26	.70	21.85	.68	23.94	.67	25.73	.65	27.22
24	.75	14.07	.74	18.58	.72	22.17	.71	25.19	.69	28.11	.68	30.21	.67	31.77
25	.77	16.04	.75	21.12	.74	25.39	.72	28.78	.71	32.06	.69	34.72	.68	36.78
26	.78	18.10	.76	23.85	.75	28.57	.73	32.59	.72	36.21	.70	39.16	.69	41.73
27	.79	20.20	.77	26.40	.76	31.81	.74	36.20	.73	40.69	.71	43.68	.70	46.77
28	.80	22.22	.78	29.62	.77	35.44	.75	40.18	.74	44.75	.72	48.85	.71	51.96
29	.81	24.79	.79	32.66	.78	39.21	.77	44.93	.75	49.56	.74	54.26	.72	57.93
30	.82	27.57	.81	35.80	.79	43.11	.78	49.23	.76	54.52	.75	59.87	.73	64.10
31	.83	30.32	.82	39.72	.80	47.81	.79	54.34	.77	60.30	.76	66.29	.74	70.56
32	.84	33.17	.83	43.45	.81	52.35	.80	59.63	.78	66.30	.77	72.38	.75	77.84
33	.85	36.12	.84	47.66	.82	57.07	.81	65.13	.79	72.54	.78	79.31	.77	85.43
34	.87	39.17	.85	52.02	.84	62.64	.82	71.49	.81	79.01	.79	87.14	.78	93.32
35	.88	42.70	.86	56.53	.85	67.70	.83	77.41	.82	86.38	.80	94.62	.79	102.13

Table 18. — Elm; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.52	$—0.26	0.52	—	—	—	—	—	—	—	—	—	—	—
12	.53	— .11	.53	—	—	—	—	—	—	—	—	—	—	—
13	.54	.09	.54	$ 0.13	0.54	$ 0.17	0.54	$ 0.19	—	—	—	—	—	—
14	.54	.37	.55	.52	.55	.66	.55	.77	0.55	$ 0.88	—	—	—	—
15	.55	.73	.55	1.03	.55	1.29	.55	1.52	.55	1.73	0.55	$ 1.89	—	—
16	.56	1.19	.56	1.67	.56	2.05	.56	2.43	.56	2.82	.56	3.14	0.56	$ 3.39
17	.57	1.73	.57	2.43	.57	3.06	.57	3.61	.57	4.15	.57	4.64	.57	5.04
18	.58	2.42	.58	3.38	.58	4.23	.58	5.02	.58	5.78	.58	6.52	.58	7.26
19	.58	3.23	.58	4.52	.59	5.65	.59	6.71	.59	7.70	.59	8.68	.59	9.66
20	.59	4.18	.59	5.81	.59	7.28	.59	8.64	.59	9.89	.59	11.14	.59	12.39
21	.60	5.28	.60	7.32	.60	9.18	.60	10.92	.60	12.62	.60	14.18	.60	15.46
22	.61	6.53	.61	9.07	.61	11.33	.61	13.47	.61	15.53	.61	17.43	.61	19.17
23	.62	7.89	.62	10.94	.62	13.72	.62	16.30	.62	18.75	.62	21.20	.62	23.65
24	.62	9.34	.62	12.83	.62	15.96	.63	18.94	.63	22.12	.63	24.93	.63	27.56
25	.63	10.74	.63	14.70	.63	18.39	.63	21.73	.63	25.27	.63	28.63	.63	31.79
26	.64	12.18	.64	16.66	.64	20.74	.64	24.63	.64	28.52	.64	32.21	.64	35.91
27	.65	13.64	.65	18.48	.65	23.12	.65	27.34	.65	31.99	.65	35.81	.65	40.05
28	.66	15.04	.66	20.76	.66	25.76	.66	30.32	.66	35.11	.66	39.91	.66	44.28
29	.66	16.81	.66	22.92	.66	28.51	.66	33.88	.67	38.81	.67	44.19	.67	49.14
30	.67	18.73	.67	25.14	.67	31.34	.67	37.08	.67	42.61	.67	48.59	.67	54.13
31	.68	20.64	.68	27.92	.68	34.75	.68	40.89	.68	47.03	.68	53.65	.68	59.34
32	.69	22.61	.69	30.57	.69	38.05	.69	44.83	.69	51.61	.69	58.40	.69	65.20
33	.70	24.66	.70	33.55	.70	41.47	.70	48.91	.70	56.36	.70	63.82	.70	71.28
34	.70	26.77	.70	36.65	.70	45.52	.70	53.65	.71	61.28	.71	69.93	.71	77.58
35	.71	29.22	.71	39.85	.71	49.20	.71	58.04	.71	66.89	.71	75.75	.71	84.62

Table 19. — Elm; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−1.10	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	−1.18	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	−1.26	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	−1.29	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	−1.30	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	−1.26	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	−1.16	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	−1.04	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	− .84	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	− .57	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
21	.40	− .22	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
22	.40	.21	.40	0.29	.40	$ 0.36	.40	$ 0.43	.40	$ 0.49	.40	$ 0.55	.40	$ 0.61
23	.40	.73	.40	1.01	.40	1.27	.40	1.50	.40	1.73	.40	1.95	.40	2.18
24	.40	1.13	.40	1.56	.40	1.93	.40	2.29	.40	2.68	.40	3.01	.40	3.33
25	.40	1.47	.40	2.01	.40	2.51	.40	2.97	.40	3.45	.40	3.91	.40	4.33
26	.40	1.72	.40	2.36	.40	2.93	.40	3.48	.40	4.02	.40	4.54	.40	5.06
27	.40	1.93	.40	2.62	.40	3.27	.40	3.87	.40	4.52	.40	5.06	.40	5.65
28	.40	2.11	.40	2.90	.40	3.60	.40	4.23	.40	4.90	.40	5.57	.40	6.17
29	.40	2.32	.40	3.17	.40	3.94	.40	4.67	.40	5.35	.40	6.09	.40	6.76
30	.40	2.54	.40	3.41	.40	4.25	.40	5.02	.40	5.77	.40	6.57	.40	7.32
31	.40	2.75	.40	3.72	.40	4.63	.40	5.45	.40	6.26	.40	7.14	.40	7.89
32	.40	2.97	.40	4.01	.40	4.98	.40	5.87	.40	6.75	.40	7.63	.40	8.52
33	.40	3.18	.40	4.32	.40	5.34	.40	6.30	.40	7.25	.40	8.20	.40	9.16
34	.40	3.40	.40	4.65	.40	5.77	.40	6.79	.40	7.76	.40	8.85	.40	9.81
35	.40	3.65	.40	4.97	.40	6.14	.40	7.23	.40	8.33	.40	9.43	.40	10.53

Table 20. — Hickory; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.74	$ 3.57	0.71	$ 4.22	0.67	$ 4.21	0.63	—	0.59	—	0.55	—	0.51	—
17	.76	4.53	.72	5.49	.68	5.77	.64	—	.61	—	.57	—	.53	—
18	.77	5.76	.74	7.03	.70	7.53	.66	—	.62	—	.58	—	.55	—
19	.79	7.15	.75	8.84	.71	9.64	.68	$ 9.75	.64	—	.60	—	.56	—
20	.81	8.74	.77	10.87	.73	12.01	.69	12.39	.65	—	.61	—	.58	—
21	.82	10.53	.78	13.20	.74	14.78	.71	15.49	.67	—	.63	—	.59	—
22	.84	12.55	.80	15.87	.76	17.88	.72	18.95	.68	$ 19.18	.65	—	.61	—
23	.85	14.69	.81	18.67	.78	21.29	.74	22.77	.70	23.28	.66	—	.62	—
24	.87	17.11	.83	21.65	.79	24.61	.75	26.47	.71	27.71	.68	—	.64	—
25	.88	19.50	.84	24.66	.81	28.32	.77	30.48	.73	31.99	.69	$ 32.32	.65	—
26	.90	22.04	.86	27.94	.82	32.04	.78	34.79	.75	36.52	.71	37.00	.67	—
27	.91	24.65	.88	31.03	.84	35.86	.80	38.91	.76	41.45	.72	41.83	.69	—
28	.93	27.19	.89	34.94	.85	40.14	.81	43.50	.78	46.01	.74	47.36	.70	—
29	.94	30.39	.91	38.66	.87	44.63	.83	48.95	.79	51.40	.75	53.21	.72	$ 53.26
30	.96	33.87	.92	42.51	.88	49.29	.85	53.97	.81	57.01	.77	59.33	.73	59.76
31	.98	37.33	.94	47.31	.90	54.90	.86	59.91	.82	63.53	.79	66.35	.75	66.62
32	.99	40.92	.95	51.90	.91	60.36	.88	66.10	.84	70.35	.80	73.11	.76	74.37
33	1.01	44.64	.97	57.09	.93	66.04	.89	72.56	.85	77.48	.82	80.81	.78	82.53
34	1.02	48.50	.98	62.48	.95	72.76	.91	80.05	.87	84.93	.83	89.51	.79	91.08
35	1.04	52.95	1.00	68.06	.96	78.91	.92	87.06	.89	93.41	.85	97.94	.81	100.65

Table 21. — Hickory; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.57	$ 0.14	0.55	—	0.54	—	0.52	—	0.50	—	—	—	—	—
15	.58	.80	.56	$ 0.80	.54	—	.52	—	.51	—	0.49	—	—	—
16	.58	1.24	.57	1.37	.55	—	.53	—	.51	—	.49	—	0.48	—
17	.59	1.76	.57	2.06	.56	$ 2.06	.54	—	.52	—	.50	—	.48	—
18	.60	2.43	.58	2.92	.56	3.06	.54	—	.53	—	.51	—	.49	—
19	.60	3.21	.59	3.95	.57	4.27	.55	$ 4.27	.53	—	.51	—	.50	—
20	.61	4.12	.59	5.13	.58	5.67	.56	5.85	.54	—	.52	—	.50	—
21	.62	5.17	.60	6.50	.58	7.32	.56	7.73	.55	$ 7.79	.53	—	.51	—
22	.62	6.36	.61	8.10	.59	9.20	.57	9.85	.55	10.10	.53	—	.52	—
23	.63	7.65	.61	9.82	.60	11.31	.58	12.24	.56	12.71	.54	$ 12.83	.52	—
24	.64	9.02	.62	11.52	.60	13.24	.58	14.42	.57	15.33	.55	15.59	.53	—
25	.64	10.34	.63	13.19	.61	15.31	.59	16.69	.57	17.77	.55	18.29	.54	—
26	.65	11.68	.63	14.93	.62	17.29	.60	19.00	.58	20.22	.56	20.84	.54	$ 21.01
27	.66	13.02	.64	16.52	.62	19.27	.60	21.14	.59	22.82	.57	23.39	.55	23.76
28	.66	14.30	.65	18.52	.63	21.46	.61	23.19	.59	25.16	.57	26.26	.56	26.56
29	.67	15.92	.65	20.40	.64	23.75	.62	26.29	.60	27.92	.58	29.29	.56	29.78
30	.68	17.67	.66	22.33	.64	26.09	.62	28.82	.61	30.76	.59	32.40	.57	33.11
31	.68	19.40	.67	24.75	.65	28.92	.63	31.82	.61	34.07	.59	35.98	.58	36.60
32	.69	21.19	.67	27.03	.66	31.65	.64	34.93	.62	37.50	.60	39.38	.58	40.55
33	.70	23.03	.68	29.62	.66	34.48	.64	38.15	.63	41.08	.61	43.25	.59	44.66
34	.70	24.93	.69	32.29	.67	37.83	.65	41.89	.63	44.79	.61	47.62	.60	48.96
35	.71	27.14	.69	35.05	.68	40.86	.66	45.37	.64	49.02	.62	51.82	.60	53.76

Table 22. — Hickory; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.46	$−0.79	0.46	—	—	—	—	—	—	—	—	—	—	—
12	.46	− .81	.46	—	0.46	—	—	—	—	—	—	—	—	—
13	.46	− .82	.46	—	.46	—	0.46	—	—	—	—	—	—	—
14	.46	− .79	.46	—	.46	—	.46	—	0.46	—	—	—	—	—
15	.46	− .71	.46	—	.46	—	.46	—	.46	—	0.46	—	—	—
16	.46	− .59	.46	—	.46	—	.46	—	.46	—	.46	—	0.46	—
17	.46	− .40	.46	—	.46	—	.46	—	.46	—	.46	—	.46	—
18	.46	− .17	.46	—	.46	—	.46	—	.46	—	.46	—	.46	—
19	.46	.14	.46	$ 0.19	.46	$ 0.24	.46	$ 0.28	.46	$ 0.32	.46	$ 0.36	.46	$ 0.40
20	.46	.52	.46	.72	.46	.91	.46	1.07	.46	1.23	.46	1.38	.46	1.53
21	.46	.99	.46	1.37	.46	1.72	.46	2.04	.46	2.35	.46	2.64	.46	2.88
22	.46	1.55	.46	2.15	.46	2.68	.46	3.18	.46	3.66	.46	4.11	.46	4.51
23	.46	2.19	.46	3.03	.46	3.80	.46	4.51	.46	5.18	.46	5.86	.46	6.53
24	.46	2.75	.46	3.77	.46	4.69	.46	5.56	.46	6.49	.46	7.30	.46	8.07
25	.46	3.23	.46	4.42	.46	5.52	.46	6.52	.46	7.58	.46	8.58	.46	9.52
26	.46	3.61	.46	4.98	.46	6.20	.46	7.35	.46	8.50	.46	9.60	.46	10.69
27	.46	4.01	.46	5.43	.46	6.79	.46	8.03	.46	9.39	.46	10.50	.46	11.73
28	.46	4.33	.46	5.98	.46	7.41	.46	8.71	.46	10.08	.46	11.45	.46	12.70
29	.46	4.74	.46	6.46	.46	8.03	.46	9.54	.46	10.92	.46	12.42	.46	13.80
30	.46	5.17	.46	6.93	.46	8.63	.46	10.21	.46	11.72	.46	13.36	.46	14.87
31	.46	5.57	.46	7.53	.46	9.37	.46	11.01	.46	12.66	.46	14.43	.46	15.95
32	.46	5.97	.46	8.07	.46	10.04	.46	11.82	.46	13.60	.46	15.38	.46	17.16
33	.46	6.38	.46	8.68	.46	10.72	.46	12.63	.46	14.55	.46	16.46	.46	18.37
34	.46	6.79	.46	9.29	.46	11.53	.46	13.58	.46	15.50	.46	17.68	.46	19.60
35	.46	7.27	.46	9.90	.46	12.22	.46	14.40	.46	16.59	.46	18.77	.46	20.96

Table 23. — Hickory; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−1.19	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	−1.29	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	−1.39	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	−1.45	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	−1.49	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	−1.47	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	−1.40	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	−1.31	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	−1.14	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	− .91	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
21	.40	− .60	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
22	.40	− .21	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
23	.40	.27	.40	$ 0.38	.40	$ 0.48	.40	$ 0.56	.40	$ 0.65	.40	$ 0.73	.40	$ 0.82
24	.40	.63	.40	.86	.40	1.07	.40	1.27	.40	1.49	.40	1.67	.40	1.85
25	.40	.92	.40	1.26	.40	1.57	.40	1.86	.40	2.16	.40	2.45	.40	2.71
26	.40	1.12	.40	1.54	.40	1.91	.40	2.27	.40	2.62	.40	2.96	.40	3.30
27	.40	1.28	.40	1.74	.40	2.17	.40	2.57	.40	3.00	.40	3.36	.40	3.75
28	.40	1.41	.40	1.94	.40	2.41	.40	2.83	.40	3.28	.40	3.73	.40	4.13
29	.40	1.57	.40	2.14	.40	2.66	.40	3.15	.40	3.61	.40	4.11	.40	4.56
30	.40	1.72	.40	2.31	.40	2.88	.40	3.40	.40	3.91	.40	4.45	.40	4.96
31	.40	1.87	.40	2.53	.40	3.15	.40	3.71	.40	4.26	.40	4.86	.40	5.37
32	.40	2.03	.40	2.74	.40	3.40	.40	4.01	.40	4.61	.40	5.21	.40	5.82
33	.40	2.18	.40	2.96	.40	3.66	.40	4.32	.40	4.97	.40	5.62	.40	6.28
34	.40	2.31	.40	3.20	.40	3.97	.40	4.67	.40	5.34	.40	6.09	.40	6.75
35	.40	2.52	.40	3.43	.40	4.24	.40	4.99	.40	5.75	.40	6.51	.40	7.27

Table 24. — Red maple; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.78	$ 8.30	0.74	$ 10.42	0.70	$ 11.30	0.66	$ 11.64	0.61	—	0.57	—	0.53	—
17	.80	10.04	.76	12.78	.72	14.32	.68	14.87	.63	—	.59	—	.55	—
18	.83	12.31	.78	15.61	.74	17.60	.70	18.56	.65	$ 18.76	.61	—	.57	—
19	.85	14.78	.80	18.88	.76	21.45	.72	22.86	.67	23.29	.63	—	.59	—
20	.87	17.56	.82	22.45	.78	25.67	.74	27.61	.70	28.30	.65	—	.61	—
21	.89	20.66	.84	26.51	.80	30.52	.76	33.12	.72	34.56	.67	$ 34.68	.63	—
22	.91	24.11	.86	31.10	.82	35.88	.78	39.12	.74	41.01	.69	41.47	.65	—
23	.93	27.69	.88	35.81	.84	41.66	.80	45.62	.76	48.03	.71	49.30	.67	$ 49.42
24	.95	31.92	.91	41.01	.86	47.47	.82	52.15	.78	56.01	.73	57.62	.69	57.62
25	.97	36.13	.93	46.35	.88	54.11	.84	59.38	.80	63.77	.75	66.24	.71	66.91
26	.99	40.70	.95	52.29	.90	60.90	.86	67.33	.82	72.21	.78	75.07	.73	76.47
27	1.01	45.42	.97	57.92	.92	67.93	.88	74.99	.84	81.51	.80	84.25	.75	86.44
28	1.03	50.03	.99	65.10	.94	75.86	.90	83.56	.86	90.10	.82	94.86	.77	96.87
29	1.05	55.85	1.01	71.90	.96	84.15	.92	93.75	.88	100.24	.84	106.02	.79	108.86
30	1.07	62.19	1.03	78.95	.99	92.76	.94	103.11	.90	110.82	.86	117.69	.81	121.42
31	1.09	68.48	1.05	87.76	1.01	103.13	.96	114.18	.92	123.11	.88	131.08	.83	134.63
32	1.11	75.00	1.07	96.16	1.03	113.21	.98	125.72	.94	135.94	.90	143.89	.86	149.57
33	1.13	81.75	1.09	105.66	1.05	123.69	1.00	137.73	.96	149.33	.92	158.49	.88	165.21
34	1.15	88.75	1.11	115.50	1.07	136.07	1.02	151.64	.98	163.26	.94	174.98	.90	181.56
35	1.17	96.83	1.13	125.71	1.09	147.37	1.04	164.63	1.00	179.14	.96	190.87	.92	199.85

Table 25. — Red maple; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.67	$ 4.22	0.64	$ 5.23	0.61	$ 5.85	0.58	$ 5.86	0.55	—	—	—	—	—
15	.67	5.15	.64	6.42	.61	7.09	.58	7.24	.55	—	0.52	—	—	—
16	.68	6.14	.65	7.75	.62	8.44	.58	8.74	.55	—	.52	—	0.49	—
17	.68	7.21	.65	9.17	.62	10.28	.59	10.68	.56	—	.53	—	.49	—
18	.68	8.59	.65	10.87	.62	12.21	.59	12.83	.56	$ 12.91	.53	—	.50	—
19	.68	10.06	.65	12.79	.62	14.15	.59	15.29	.56	15.44	.53	—	.50	—
20	.68	11.68	.65	14.84	.62	16.84	.59	17.94	.56	18.18	.53	—	.50	—
21	.69	13.47	.66	17.15	.63	19.56	.59	20.98	.56	21.59	.53	—	.50	—
22	.69	15.43	.66	19.72	.63	22.51	.60	24.23	.57	25.02	.54	—	.50	—
23	.69	17.42	.66	22.30	.63	25.65	.60	27.70	.57	28.69	.54	$ 28.85	.51	—
24	.69	19.68	.66	25.00	.63	28.57	.60	30.92	.57	32.61	.54	32.82	.51	$ 31.94
25	.69	21.81	.66	27.64	.63	31.81	.60	34.33	.57	36.15	.54	36.66	.51	35.96
26	.70	24.03	.67	30.46	.64	34.92	.60	37.90	.57	39.78	.54	40.29	.51	39.76
27	.70	26.22	.67	32.94	.64	37.98	.61	41.10	.58	43.63	.55	43.85	.51	43.48
28	.70	28.25	.67	36.17	.64	41.37	.61	44.60	.58	46.89	.55	47.91	.52	47.18
29	.70	30.87	.67	39.06	.64	44.81	.61	48.79	.58	50.79	.55	52.03	.52	51.41
30	.70	33.66	.67	41.95	.64	48.26	.61	52.35	.58	54.69	.55	56.17	.52	55.66
31	.71	36.32	.68	45.65	.65	52.46	.61	56.61	.58	59.25	.55	60.91	.52	59.99
32	.71	39.00	.68	48.99	.65	56.35	.62	60.92	.59	63.87	.56	65.18	.52	64.86
33	.71	41.70	.68	52.76	.65	60.28	.62	65.28	.59	68.54	.56	70.05	.53	69.81
34	.71	44.43	.68	56.56	.65	64.98	.62	70.36	.59	73.27	.56	75.54	.53	74.84
35	.71	47.61	.68	60.41	.65	69.00	.62	74.83	.59	78.68	.56	80.55	.53	80.44

Table 26. — Red maple; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.46	$ 0.34	0.46	$ 0.47	—	—	—	—	—	—	—	—	—	—
12	.46	.53	.46	.73	0.46	$ 0.89	—	—	—	—	—	—	—	—
13	.46	.78	.46	1.08	.46	1.31	0.46	$ 1.47	—	—	—	—	—	—
14	.46	1.07	.46	1.48	.46	1.86	.46	2.14	.46	$ 2.38	—	—	—	—
15	.46	1.45	.46	2.00	.46	2.47	.46	2.88	.46	3.24	0.46	$ 3.48	—	—
16	.46	1.88	.46	2.62	.46	3.17	.46	3.72	.46	4.28	.46	4.70	.46	$ 5.02
17	.46	2.38	.46	3.32	.46	4.12	.46	4.82	.46	5.48	.46	6.08	.46	6.53
18	.46	3.01	.46	4.16	.46	5.17	.46	6.07	.46	6.94	.46	7.75	.46	8.55
19	.46	3.72	.46	5.16	.46	6.41	.46	7.54	.46	8.59	.46	9.60	.46	10.60
20	.46	4.54	.46	6.26	.46	7.78	.46	9.17	.46	10.42	.46	11.65	.46	12.87
21	.46	5.45	.46	7.52	.46	9.36	.46	11.07	.46	12.70	.46	14.17	.46	15.35
22	.46	6.49	.46	8.96	.46	11.12	.46	13.14	.46	15.05	.46	16.79	.46	18.36
23	.46	7.58	.46	10.46	.46	13.04	.46	15.41	.46	17.62	.46	19.81	.46	21.97
24	.46	8.71	.46	11.91	.46	14.73	.46	17.39	.46	20.19	.46	22.63	.46	24.88
25	.46	9.74	.46	13.26	.46	16.51	.46	19.40	.46	22.45	.46	25.29	.46	27.94
26	.46	10.75	.46	14.63	.46	18.12	.46	21.40	.46	24.65	.46	27.70	.46	30.72
27	.46	11.72	.46	15.80	.46	19.66	.46	23.13	.46	26.93	.46	29.98	.46	33.36
28	.46	12.59	.46	17.29	.46	21.34	.46	24.99	.46	28.79	.46	32.56	.46	35.94
29	.46	13.72	.46	18.61	.46	23.02	.46	27.22	.46	31.03	.46	35.15	.46	38.88
30	.46	14.91	.46	19.91	.46	24.69	.46	29.07	.46	33.23	.46	37.70	.46	41.79
31	.46	16.03	.46	21.58	.46	26.73	.46	31.28	.46	35.80	.46	40.63	.46	44.71
32	.46	17.15	.46	23.07	.46	28.58	.46	33.50	.46	38.38	.46	43.21	.46	48.00
33	.46	18.28	.46	24.75	.46	30.45	.46	35.73	.46	40.96	.46	46.15	.46	51.29
34	.46	19.41	.46	26.44	.46	32.68	.46	38.32	.46	43.55	.46	49.46	.46	54.59
35	.46	20.73	.46	28.13	.46	34.55	.46	40.56	.46	46.52	.46	52.42	.46	58.27

Table 27. — Red maple; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$—0.23	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	— .15	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	— .03	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	.13	.40	$ 0.18	.40	$ 0.23	.40	$ 0.27	.40	$ 0.31	.40	—	.40	—
15	.40	.35	.40	.49	.40	.61	.40	.72	.40	.82	.40	$ 0.89	.40	—
16	.40	.63	.40	.88	.40	1.08	.40	1.28	.40	1.48	.40	1.64	.40	$ 1.77
17	.40	.96	.40	1.36	.40	1.70	.40	2.00	.40	2.30	.40	2.57	.40	2.78
18	.40	1.39	.40	1.94	.40	2.43	.40	2.87	.40	3.31	.40	3.72	.40	4.13
19	.40	1.90	.40	2.65	.40	3.31	.40	3.92	.40	4.50	.40	5.06	.40	5.62
20	.40	2.49	.40	3.46	.40	4.33	.40	5.13	.40	5.87	.40	6.60	.40	7.33
21	.40	3.18	.40	4.41	.40	5.52	.40	6.56	.40	7.57	.40	8.50	.40	9.26
22	.40	3.97	.40	5.51	.40	6.88	.40	8.17	.40	9.40	.40	10.54	.40	11.59
23	.40	4.83	.40	6.70	.40	8.40	.40	9.96	.40	11.45	.40	12.93	.40	14.42
24	.40	5.67	.40	7.78	.40	9.67	.40	11.47	.40	13.39	.40	15.07	.40	16.65
25	.40	6.42	.40	8.78	.40	10.97	.40	12.96	.40	15.06	.40	17.05	.40	18.91
26	.40	7.12	.40	9.74	.40	12.11	.40	14.37	.40	16.62	.40	18.76	.40	20.90
27	.40	7.78	.40	10.54	.40	13.17	.40	15.57	.40	18.20	.40	20.36	.40	22.75
28	.40	8.37	.40	11.54	.40	14.31	.40	16.83	.40	19.48	.40	22.13	.40	24.53
29	.40	9.13	.40	12.44	.40	15.46	.40	18.35	.40	21.01	.40	23.91	.40	26.56
30	.40	9.92	.40	13.31	.40	16.58	.40	19.60	.40	22.51	.40	25.65	.40	28.56
31	.40	10.67	.40	14.13	.40	17.95	.40	21.11	.40	24.26	.40	27.66	.40	30.57
32	.40	11.43	.40	15.44	.40	19.20	.40	22.61	.40	26.01	.40	29.41	.40	32.82
33	.40	12.18	.40	16.56	.40	20.46	.40	24.12	.40	27.77	.40	31.42	.40	35.08
34	.40	12.94	.40	17.70	.40	21.97	.40	25.87	.40	29.54	.40	33.69	.40	37.35
35	.40	13.82	.40	18.83	.40	23.24	.40	27.39	.40	31.55	.40	35.71	.40	39.87

Table 28. — Sugar maple; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.84	$ 9.01	0.79	$ 11.28	0.74	$ 12.17	0.69	$ 12.46	0.65	—	0.60	—	0.55	—
17	.86	10.86	.81	13.76	.77	15.35	.72	15.84	.67	—	.62	—	.57	—
18	.89	13.25	.84	16.75	.79	18.79	.74	19.69	.69	$ 19.75	.64	—	.59	—
19	.91	15.86	.86	20.19	.81	22.83	.76	24.19	.71	24.45	.66	—	.61	—
20	.93	18.79	.88	23.94	.83	27.24	.78	29.12	.73	29.64	.68	—	.63	—
21	.95	22.06	.90	28.19	.85	32.31	.80	34.86	.75	36.12	.70	—	.66	—
22	.97	25.69	.92	33.00	.87	37.89	.82	41.09	.78	42.79	.73	$ 42.92	.68	—
23	.99	29.44	.94	37.92	.90	43.91	.85	47.84	.80	50.04	.75	50.97	.70	—
24	1.02	33.88	.97	43.36	.92	49.97	.87	54.62	.82	58.30	.77	59.54	.72	—
25	1.04	38.31	.99	48.95	.94	56.90	.89	62.14	.84	66.33	.79	68.42	.74	$ 68.54
26	1.06	43.12	1.01	55.19	.96	64.00	.91	70.41	.86	75.08	.81	77.53	.76	78.35
27	1.08	48.08	1.03	61.08	.98	71.34	.93	78.38	.88	84.72	.83	87.00	.79	88.58
28	1.10	52.91	1.05	68.61	1.00	79.62	.95	87.29	.91	93.63	.86	97.95	.81	99.30
29	1.12	59.03	1.08	75.73	1.03	88.28	.98	97.90	.93	104.14	.88	109.48	.83	111.62
30	1.15	65.69	1.10	83.11	1.05	97.27	1.00	107.63	.95	115.10	.90	121.53	.85	124.53
31	1.17	72.29	1.12	92.33	1.07	108.09	1.02	119.15	.97	127.84	.92	135.35	.87	138.11
32	1.19	79.13	1.14	101.12	1.09	118.60	1.04	131.15	.99	141.14	.94	148.57	.89	153.46
33	1.21	86.21	1.16	111.05	1.11	129.53	1.06	143.63	1.01	155.00	.96	163.64	.92	169.54
34	1.23	93.54	1.18	121.35	1.13	142.43	1.09	158.09	1.04	169.44	.99	180.66	.94	186.36
35	1.25	102.01	1.21	132.01	1.16	154.21	1.11	171.60	1.06	185.88	1.01	197.07	.96	205.16

Table 29. — Sugar maple; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.60	$ 2.88	0.59	$ 3.76	0.57	$ 4.17	0.56	$ 4.83	0.55	$ 5.03	—	—	—	—
15	.61	3.79	.60	4.98	.59	5.86	.58	6.15	.56	6.85	0.55	$ 6.90	—	—
16	.63	4.82	.61	6.41	.60	7.43	.59	8.31	.58	9.07	.56	9.14	0.55	$ 9.48
17	.64	5.97	.63	8.02	.62	9.57	.60	10.71	.59	11.64	.58	12.29	.57	12.53
18	.65	7.46	.64	9.96	.63	11.91	.62	13.16	.60	14.76	.59	15.78	.58	16.62
19	.67	9.12	.66	12.23	.64	14.68	.63	16.68	.62	18.30	.61	19.66	.59	20.81
20	.68	10.99	.67	14.72	.66	17.73	.64	20.24	.63	22.21	.62	23.96	.61	25.48
21	.69	13.11	.68	17.58	.67	21.25	.66	24.38	.65	27.10	.63	29.26	.62	30.61
22	.71	15.48	.70	20.82	.68	25.16	.67	28.90	.66	32.11	.65	34.76	.63	36.81
23	.72	17.97	.71	24.18	.70	29.40	.69	33.81	.67	37.61	.66	41.10	.65	44.26
24	.74	20.82	.72	27.80	.71	33.57	.70	38.65	.69	43.73	.67	47.71	.66	51.00
25	.75	23.66	.74	31.18	.72	38.28	.71	43.93	.70	49.58	.69	54.45	.68	58.56
26	.76	26.69	.75	35.53	.74	43.03	.73	49.67	.71	55.86	.70	61.24	.69	66.20
27	.78	29.80	.76	39.34	.75	47.91	.74	55.14	.73	62.73	.72	68.21	.70	74.07
28	.79	32.82	.78	44.18	.77	53.40	.75	61.22	.74	68.99	.73	76.25	.72	82.21
29	.80	36.65	.79	48.75	.78	59.12	.77	68.47	.75	76.39	.74	84.66	.73	91.55
30	.82	40.81	.81	53.49	.79	65.05	.78	75.07	.77	81.06	.76	93.39	.74	101.26
31	.83	44.94	.82	59.41	.81	72.19	.79	82.88	.78	92.98	.77	103.39	.76	111.39
32	.85	49.22	.83	65.04	.82	79.11	.81	91.00	.80	102.25	.78	112.87	.77	122.84
33	.86	53.65	.85	71.41	.83	86.29	.82	99.43	.81	111.89	.80	123.66	.78	131.75
34	.87	58.24	.86	78.00	.85	94.77	.84	109.20	.82	121.88	.81	135.85	.80	147.12
35	.89	63.54	.87	84.83	.86	102.49	.85	118.27	.84	133.27	.82	147.50	.81	160.95

Table 30. — Sugar maple; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.44	$ 0.04	0.43	—	—	—	—	—	—	—	—	—	—	—
12	.45	.27	.43	—	0.42	—	—	—	—	—	—	—	—	—
13	.46	.59	.44	—	.43	—	0.41	—	—	—	—	—	—	—
14	.47	1.00	.45	$ 1.06	.44	—	.42	—	0.41	—	—	—	—	—
15	.48	1.52	.46	1.74	.45	—	.43	—	.42	—	0.40	—	—	—
16	.49	2.15	.47	2.57	.46	$ 2.62	.44	—	.42	—	.41	—	0.39	—
17	.50	2.88	.48	3.56	.47	3.84	.45	—	.43	—	.42	—	.40	—
18	.51	3.82	.49	4.77	.48	5.26	.46	$ 5.40	.44	—	.43	—	.41	—
19	.52	4.90	.50	6.21	.49	6.98	.47	7.34	.45	$ 7.34	.44	—	.42	—
20	.53	6.15	.51	7.84	.50	8.93	.48	9.55	.46	9.73	.45	—	.43	—
21	.54	7.58	.52	9.73	.50	11.21	.49	12.17	.47	12.71	.46	$ 12.77	.44	—
22	.55	9.21	.53	11.91	.51	13.80	.50	15.11	.48	15.93	.47	16.21	.45	—
23	.56	10.95	.54	14.23	.52	16.66	.51	18.38	.49	19.52	.48	20.24	.46	$ 20.54
24	.57	12.87	.55	16.64	.53	19.41	.52	21.51	.50	23.33	.49	24.28	.47	24.62
25	.57	14.76	.56	19.07	.54	22.44	.53	24.86	.51	26.97	.49	28.36	.48	29.07
26	.58	16.75	.57	21.68	.55	25.46	.54	28.40	.52	30.79	.50	32.40	.49	33.48
27	.59	18.79	.58	24.13	.56	28.53	.55	31.79	.53	34.92	.51	36.53	.50	38.01
28	.60	20.77	.59	27.22	.57	31.97	.56	35.54	.54	38.72	.52	41.25	.51	42.71
29	.61	23.26	.60	30.16	.58	35.58	.56	40.00	.55	43.21	.53	46.23	.52	48.11
30	.62	25.97	.61	33.21	.59	39.33	.57	44.10	.56	47.88	.54	51.42	.53	53.74
31	.63	28.67	.62	37.01	.60	43.83	.58	48.95	.57	53.30	.55	57.38	.54	59.68
32	.64	31.48	.63	40.65	.61	48.23	.59	54.01	.58	58.97	.56	63.10	.55	66.39
33	.65	34.40	.63	44.76	.62	52.80	.60	59.29	.59	64.89	.57	69.61	.55	73.43
34	.66	37.42	.64	49.04	.63	58.20	.61	65.41	.60	71.07	.58	76.96	.56	80.79
35	.67	40.91	.65	53.48	.64	63.16	.62	71.14	.61	78.11	.59	84.07	.57	89.02

Table 31. — Sugar maple; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−0.34	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	− .27	.40		.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	− .17	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	− .03	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	.17	.40	$ 0.24	.40	$ 0.30	.40	$ 0.35	.40	—	.40	—	.40	—
16	.40	.43	.40	.60	.40	.74	.40	.87	.40	$ 1.01	.40	$ 1.13	.40	—
17	.40	.74	.40	1.05	.40	1.31	.40	1.55	.40	1.78	.40	1.99	.40	—
18	.40	1.15	.40	1.60	.40	2.00	.40	2.37	.40	2.73	.40	3.07	.40	$ 3.41
19	.40	1.63	.40	2.27	.40	2.84	.40	3.37	.40	3.87	.40	4.35	.40	4.84
20	.40	2.20	.40	3.05	.40	3.82	.40	4.53	.40	5.18	.40	5.83	.40	6.48
21	.40	2.86	.40	3.97	.40	4.97	.40	5.91	.40	6.82	.40	7.66	.40	8.34
22	.40	3.63	.40	5.03	.40	6.29	.40	7.47	.40	8.60	.40	9.65	.40	10.60
23	.40	4.47	.40	6.19	.40	7.76	.40	9.22	.40	10.59	.40	11.97	.40	13.35
24	.40	5.28	.40	7.25	.40	9.01	.40	10.69	.40	12.47	.40	14.05	.40	15.52
25	.40	6.00	.40	8.21	.40	10.27	.40	12.13	.40	14.10	.40	15.96	.40	17.71
26	.40	6.68	.40	9.14	.40	11.37	.40	13.49	.40	15.61	.40	17.62	.40	19.64
27	.40	7.32	.40	9.91	.40	12.39	.40	14.65	.40	17.14	.40	19.17	.40	21.43
28	.40	7.89	.40	10.88	.40	13.19	.40	15.88	.40	18.38	.40	20.88	.40	23.16
29	.40	8.62	.40	11.75	.40	14.61	.40	17.35	.40	19.87	.40	22.61	.40	25.13
30	.40	9.39	.40	12.60	.40	15.70	.40	18.57	.40	21.33	.40	24.31	.40	27.07
31	.40	10.13	.40	13.70	.40	17.04	.40	20.04	.40	23.03	.40	26.27	.40	29.04
32	.40	10.86	.40	14.68	.40	18.26	.40	21.51	.40	24.75	.40	27.99	.40	31.24
33	.40	11.60	.40	15.78	.40	19.50	.40	22.99	.40	26.48	.40	29.97	.40	33.46
34	.40	12.35	.40	16.89	.40	20.98	.40	24.71	.40	28.22	.40	32.19	.40	35.70
35	.40	13.22	.40	18.01	.40	22.23	.40	26.22	.40	30.20	.40	34.19	.40	38.18

Table 32. — Black oak; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.93	$ 7.76	0.89	$ 9.89	0.84	$ 10.91	0.80	$ 11.50	0.76	$ 11.70	0.71	—	0.67	—
17	.94	9.23	.90	11.88	.86	13.51	.81	14.28	.77	14.52	.73	—	.69	—
18	.96	11.14	.91	14.26	.87	16.27	.83	17.40	.78	17.90	.74	—	.70	—
19	.97	13.19	.93	16.99	.88	19.48	.84	21.00	.80	21.69	.76	$ 21.71	.71	—
20	.98	15.48	.94	19.93	.90	22.95	.85	24.91	.81	25.82	.77	26.06	.73	—
21	1.00	18.02	.95	23.25	.91	26.93	.87	29.43	.83	30.97	.78	31.41	.74	—
22	1.01	20.83	.97	26.98	.93	31.27	.88	34.30	.84	36.20	.80	36.90	.75	—
23	1.02	23.71	.98	30.76	.94	35.92	.90	39.52	.85	41.82	.81	43.20	.77	$ 43.64
24	1.04	27.07	1.00	34.87	.95	40.48	.91	44.63	.87	48.12	.82	49.74	.78	50.03
25	1.05	30.36	1.01	39.01	.97	45.65	.92	50.22	.88	54.08	.84	56.37	.80	57.17
26	1.07	33.88	1.02	43.58	.98	50.82	.94	56.27	.89	60.47	.85	63.00	.81	64.34
27	1.08	37.45	1.04	47.79	.99	56.09	.95	61.97	.91	67.42	.87	69.76	.82	71.66
28	1.09	40.88	1.05	53.20	1.01	62.00	.96	68.30	.92	73.66	.88	77.55	.84	79.22
29	1.11	45.25	1.06	58.23	1.02	68.11	.98	75.84	.94	81.05	.89	85.66	.85	87.88
30	1.12	49.97	1.08	63.38	1.03	74.39	.99	82.60	.95	88.66	.91	94.02	.86	96.84
31	1.13	54.59	1.09	69.87	1.05	81.99	1.01	90.62	.96	97.52	.92	103.61	.88	106.16
32	1.15	59.33	1.11	75.95	1.06	89.21	1.02	98.89	.98	106.68	.93	112.61	.89	116.68
33	1.16	64.21	1.12	82.81	1.08	96.72	1.03	107.42	.99	116.14	.95	122.86	.90	127.59
34	1.18	69.21	1.13	89.87	1.09	105.59	1.05	117.33	1.00	125.90	.96	134.44	.92	138.90
35	1.19	75.01	1.15	97.12	1.10	113.52	1.06	126.41	1.02	137.03	.98	145.41	.93	151.52

Table 33. — Black oak; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.64	$ 2.01	0.63	$ 2.60	0.62	$ 3.05	0.61	$ 3.25	0.60	$ 3.32	—	—	—	—
15	.65	2.69	.64	3.50	.63	4.08	.62	4.41	.61	4.66	0.59	—	—	—
16	.66	3.46	.65	4.57	.64	5.26	.63	5.83	.62	6.30	.60	$ 6.47	0.59	—
17	.67	4.32	.66	5.77	.65	6.85	.64	7.61	.63	8.21	.61	8.58	.60	$ 8.66
18	.68	5.45	.67	7.23	.66	8.61	.65	9.66	.64	10.53	.62	11.17	.61	11.67
19	.69	6.69	.68	8.94	.67	10.69	.66	12.08	.65	13.18	.63	14.07	.62	14.80
20	.70	8.12	.69	10.83	.68	12.99	.67	14.76	.66	16.13	.64	17.31	.63	18.30
21	.71	9.73	.70	12.99	.69	15.66	.68	17.89	.67	19.81	.65	21.29	.64	22.17
22	.72	11.53	.71	15.46	.70	18.62	.69	21.32	.68	23.63	.66	25.46	.65	26.85
23	.73	13.43	.72	18.03	.71	21.86	.70	25.07	.69	27.79	.67	30.26	.66	32.47
24	.74	15.56	.73	20.72	.72	24.95	.71	28.65	.70	32.32	.68	35.14	.67	37.44
25	.75	17.64	.74	23.42	.73	28.40	.72	32.50	.71	36.57	.69	40.04	.68	42.92
26	.76	19.82	.75	26.33	.74	31.80	.73	36.60	.72	41.05	.70	44.86	.69	48.33
27	.77	22.04	.76	29.02	.75	35.26	.74	40.46	.73	45.89	.71	49.75	.70	53.83
28	.78	24.17	.77	32.45	.76	39.12	.75	44.72	.74	50.24	.72	55.35	.71	59.47
29	.79	26.88	.78	35.66	.77	43.12	.76	49.80	.75	55.39	.73	61.19	.72	65.94
30	.80	29.80	.79	38.96	.78	47.25	.77	54.36	.76	60.69	.74	67.20	.73	72.61
31	.81	32.69	.80	43.10	.79	52.22	.78	59.78	.77	66.86	.75	74.10	.74	79.55
32	.82	35.66	.81	47.00	.80	57.01	.79	65.38	.78	73.24	.76	80.57	.75	87.38
33	.83	38.74	.82	51.42	.81	61.95	.80	71.18	.79	79.84	.77	87.95	.76	95.50
34	.84	41.90	.83	55.97	.82	67.81	.81	77.89	.79	86.67	.78	96.28	.77	103.90
35	.85	45.57	.84	60.67	.83	73.09	.82	84.08	.80	94.45	.79	104.18	.78	113.28

Table 34. — Black oak; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.57	$ 0.34	0.55	$ 0.35	—	—	—	—	—	—	—	—	—	—
12	.57	.56	.56	.62	0.55	—	—	—	—	—	—	—	—	—
13	.57	.85	.56	1.01	.55	$ 1.01	0.54	—	—	—	—	—	—	—
14	.58	1.20	.56	1.46	.55	1.58	.54	—	0.53	—	—	—	—	—
15	.58	1.65	.57	2.04	.56	2.24	.54	$ 2.27	.53	—	0.52	—	—	—
16	.58	2.16	.57	2.74	.56	3.01	.55	3.15	.53	$ 3.17	.52	—	0.51	—
17	.59	2.75	.58	3.55	.56	4.04	.55	4.29	.54	4.37	.53	—	.51	—
18	.59	3.51	.58	4.53	.57	5.21	.55	5.62	.54	5.85	.53	$ 5.88	.52	—
19	.60	4.37	.58	5.68	.57	6.59	.56	7.20	.55	7.55	.53	7.71	.52	—
20	.60	5.35	.59	6.97	.57	8.14	.56	8.98	.55	9.48	.54	9.79	.52	$ 9.91
21	.60	6.46	.59	8.45	.58	9.94	.56	11.06	.55	11.89	.54	12.36	.53	12.39
22	.61	7.71	.59	10.14	.58	11.95	.57	13.36	.56	14.42	.54	15.09	.53	15.40
23	.61	9.04	.60	11.91	.58	14.16	.57	15.90	.56	17.21	.55	18.26	.53	19.04
24	.61	10.46	.60	13.69	.59	16.17	.58	18.19	.56	20.07	.55	21.30	.54	22.08
25	.62	11.80	.60	15.40	.59	18.33	.58	20.57	.57	22.66	.55	24.22	.54	25.30
26	.62	13.15	.61	17.18	.59	20.38	.58	23.00	.57	25.25	.56	26.96	.54	28.33
27	.62	14.49	.61	18.76	.60	22.39	.59	25.20	.57	27.98	.56	29.65	.55	31.29
28	.63	15.74	.61	20.78	.60	24.61	.59	27.59	.58	30.35	.56	32.68	.55	34.26
29	.63	17.34	.62	22.63	.61	26.88	.59	30.44	.58	33.16	.57	35.81	.56	37.66
30	.63	19.06	.62	24.50	.61	29.18	.60	32.93	.58	36.01	.57	38.98	.56	41.10
31	.64	20.72	.63	26.86	.61	31.97	.60	35.90	.59	39.32	.57	42.61	.56	44.65
32	.64	22.41	.63	29.05	.62	34.61	.60	38.93	.59	42.72	.58	45.95	.57	48.65
33	.64	24.14	.63	31.52	.62	37.30	.61	42.04	.59	46.19	.58	49.76	.57	52.75
34	.65	25.91	.64	34.03	.62	40.50	.61	45.64	.60	49.75	.59	54.06	.57	56.97
35	.65	27.96	.64	36.61	.63	43.32	.61	48.90	.60	53.81	.59	58.07	.58	61.67

Table 35. — Black oak; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$–0.90	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	–.95	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	–.99	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	–.97	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	–.94	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	–.84	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	–.69	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	–.50	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	–.23	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	.11	.40	$ 0.16	.40	$ 0.20	.40	$ 0.23	.40	$ 0.27	.40	$ 0.30	.40	$ 0.33
21	.40	.53	.40	.74	.40	.93	.40	1.10	.40	1.27	.40	1.43	.40	1.56
22	.40	1.04	.40	1.45	.40	1.81	.40	2.15	.40	2.47	.40	2.77	.40	3.05
23	.40	1.64	.40	2.27	.40	2.85	.40	3.38	.40	3.89	.40	4.39	.40	4.90
24	.40	2.14	.40	2.94	.40	3.65	.40	4.33	.40	5.06	.40	5.69	.40	6.29
25	.40	2.57	.40	3.52	.40	4.39	.40	5.19	.40	6.03	.40	6.83	.40	7.57
26	.40	2.92	.40	4.00	.40	4.97	.40	5.90	.40	6.82	.40	7.70	.40	8.58
27	.40	3.23	.40	4.38	.40	5.47	.40	6.47	.40	7.56	.40	8.46	.40	9.45
28	.40	3.50	.40	4.82	.40	5.98	.40	7.03	.40	8.14	.40	9.25	.40	10.25
29	.40	3.84	.40	5.23	.40	6.50	.40	7.71	.40	8.83	.40	10.05	.40	11.16
30	.40	4.18	.40	5.61	.40	6.99	.40	8.26	.40	9.49	.40	10.81	.40	12.04
31	.40	4.51	.40	6.10	.40	7.59	.40	8.93	.40	10.26	.40	11.70	.40	12.93
32	.40	4.85	.40	6.55	.40	8.14	.40	9.59	.40	11.03	.40	12.47	.40	13.92
33	.40	5.18	.40	7.04	.40	8.70	.40	10.26	.40	11.81	.40	13.36	.40	14.92
34	.40	5.52	.40	7.55	.40	9.37	.40	11.03	.40	12.60	.40	14.36	.40	15.93
35	.40	5.91	.40	8.05	.40	9.94	.40	11.71	.40	13.49	.40	15.27	.40	17.05

Table 36. — Chestnut oak; butt log grade 1

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.91	$ 5.98	0.87	$ 7.70	0.84	$ 8.61	0.81	$ 9.22	0.78	$ 9.56	0.74	—	0.71	—
17	.91	7.10	.88	9.23	.85	10.62	.82	11.39	.78	11.79	.75	—	.72	—
18	.92	8.55	.89	11.05	.86	12.75	.82	13.82	.79	14.45	.76	$ 14.62	.73	—
19	.93	10.12	.90	13.15	.86	15.23	.83	16.61	.80	17.41	.77	17.75	.73	—
20	.94	11.86	.90	15.39	.87	17.90	.84	19.64	.81	20.63	.77	21.16	.74	—
21	.94	13.79	.91	17.93	.88	20.95	.85	23.14	.81	24.65	.78	25.37	.75	—
22	.95	15.92	.92	20.78	.89	24.29	.85	26.90	.82	28.71	.79	29.67	.76	$ 29.83
23	.96	18.11	.93	23.67	.89	27.86	.86	30.92	.83	33.07	.80	34.59	.76	35.46
24	.97	20.61	.93	26.72	.90	31.26	.87	34.75	.84	37.84	.80	39.56	.77	40.33
25	.97	23.01	.94	29.75	.91	35.06	.88	38.87	.84	42.24	.81	44.49	.78	45.68
26	.98	25.54	.95	33.04	.92	38.78	.88	43.25	.85	46.86	.82	49.29	.79	50.90
27	.99	28.07	.96	36.00	.92	42.50	.89	47.28	.86	51.82	.83	54.09	.79	56.13
28	1.00	30.46	.96	39.83	.93	46.66	.90	51.72	.87	56.16	.83	59.60	.80	61.44
29	1.00	33.52	.97	43.32	.94	50.93	.91	57.02	.87	61.32	.84	65.27	.81	67.52
30	1.01	36.80	.98	46.87	.95	55.26	.91	61.66	.88	66.56	.85	71.05	.82	73.72
31	1.02	39.98	.99	51.36	.95	60.51	.92	67.19	.89	72.68	.86	77.67	.82	80.12
32	1.03	43.23	.99	55.51	.96	65.47	.93	72.84	.90	78.94	.86	83.77	.83	87.32
33	1.03	46.53	1.00	60.19	.97	70.53	.94	78.63	.90	85.36	.87	90.72	.84	94.72
34	1.04	49.91	1.01	64.97	.98	76.56	.94	85.35	.91	91.92	.88	98.56	.85	102.32
35	1.05	53.82	1.02	69.85	.98	81.85	.95	91.41	.92	99.42	.89	105.88	.85	110.79

Table 37. — Chestnut oak; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.65	$ 1.28	0.63	$ 1.56	0.62	$ 1.70	0.60	—	0.59	—	—	—	—	—
15	.66	1.80	.64	2.25	.63	2.49	.61	$ 2.54	.60	—	0.58	—	—	—
16	.66	2.41	.65	3.08	.64	3.41	.62	3.60	.61	$ 3.67	.59	—	0.58	—
17	.67	3.11	.66	4.04	.64	4.64	.63	4.97	.62	5.13	.60	—	.59	—
18	.68	4.02	.67	5.21	.65	6.04	.64	6.58	.62	6.93	.61	$ 7.07	.59	—
19	.69	5.04	.68	6.60	.66	7.71	.65	8.50	.63	9.02	.62	9.32	.60	$ 9.45
20	.70	6.21	.68	8.15	.67	9.59	.66	10.66	.64	11.38	.63	11.89	.61	12.20
21	.71	7.55	.69	9.93	.68	11.77	.66	13.20	.65	14.32	.64	15.05	.62	15.28
22	.72	9.05	.70	11.98	.69	14.22	.67	16.02	.66	17.43	.64	18.42	.63	19.01
23	.73	10.66	.71	14.13	.70	16.91	.68	19.11	.67	20.87	.65	22.31	.64	23.52
24	.73	12.42	.72	16.35	.71	19.44	.69	22.03	.68	24.50	.66	26.23	.65	27.47
25	.74	14.12	.73	18.54	.71	22.23	.70	25.12	.68	27.89	.67	30.09	.66	31.75
26	.75	15.89	.74	20.89	.72	24.95	.71	28.37	.69	31.41	.68	33.84	.66	35.92
27	.76	17.68	.75	23.04	.73	27.69	.72	31.44	.70	35.18	.69	37.63	.67	40.13
28	.77	19.39	.75	25.77	.74	30.74	.73	34.75	.71	38.57	.70	41.94	.68	44.44
29	.78	21.56	.76	28.33	.75	33.91	.73	38.73	.72	42.58	.71	46.44	.69	49.38
30	.79	23.91	.77	30.96	.76	37.17	.74	42.31	.73	46.70	.71	51.08	.70	54.47
31	.80	26.22	.78	34.26	.77	41.10	.75	46.56	.74	51.50	.72	56.40	.71	59.78
32	.80	28.61	.79	37.37	.78	44.89	.76	50.96	.75	56.46	.73	61.40	.72	65.77
33	.81	31.07	.80	40.88	.78	48.80	.77	55.51	.75	61.61	.74	67.11	.73	71.99
34	.82	33.61	.81	44.51	.79	53.43	.78	60.78	.76	66.94	.75	73.55	.73	78.44
35	.83	36.55	.82	48.25	.80	57.61	.79	65.65	.77	73.01	.76	79.67	.74	85.64

Table 38. — Chestnut oak; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.54	$—0.26	0.53	—	—	—	—	—	—	—	—	—	—	—
12	.55	— .13	.54	—	0.54	—	—	—	—	—	—	—	—	—
13	.55	.06	.55	$ 0.03	.54	—	0.54	—	—	—	—	—	—	—
14	.56	.33	.56	.38	.55	$ 0.39	.55	—	0.54	—	—	—	—	—
15	.57	.67	.56	.85	.56	.95	.55	$ 0.99	.55	—	0.54	—	—	—
16	.57	1.10	.57	1.44	.57	1.64	.56	1.80	.56	$ 1.91	.55	$ 1.94	0.55	—
17	.58	1.61	.58	2.16	.57	2.56	.57	2.85	.56	3.07	.56	3.22	.55	$ 3.25
18	.59	2.27	.58	3.04	.58	3.64	.57	4.11	.57	4.51	.56	4.83	.56	5.10
19	.60	3.04	.59	4.10	.59	4.94	.58	5.64	.58	6.22	.57	6.72	.57	7.16
20	.60	3.94	.60	5.31	.59	6.44	.59	7.40	.58	8.19	.58	8.90	.57	9.55
21	.61	4.98	.61	6.73	.60	8.20	.60	9.49	.59	10.64	.59	11.59	.58	12.25
22	.62	6.18	.61	8.37	.61	10.20	.60	11.83	.60	13.28	.59	14.51	.59	15.53
23	.63	7.47	.62	10.14	.62	12.43	.61	14.44	.61	16.22	.60	17.90	.60	19.49
24	.63	8.84	.63	11.90	.62	14.49	.62	16.84	.61	19.24	.61	21.21	.60	22.92
25	.64	10.16	.64	13.63	.63	16.72	.63	19.36	.62	22.06	.62	24.47	.61	26.60
26	.65	11.50	.64	15.44	.64	18.86	.63	21.96	.63	24.93	.62	27.60	.62	30.14
27	.65	12.86	.65	17.10	.64	21.01	.64	24.38	.63	27.99	.63	30.72	.63	33.69
28	.66	14.15	.66	19.19	.65	23.39	.65	27.03	.64	30.73	.64	34.28	.63	37.30
29	.67	15.79	.66	21.17	.66	25.87	.65	30.20	.65	33.97	.64	37.98	.64	41.45
30	.68	17.56	.67	23.19	.67	28.41	.66	33.04	.66	37.30	.65	41.79	.65	45.72
31	.68	19.32	.68	25.72	.67	31.49	.67	36.42	.66	41.18	.66	46.17	.65	50.17
32	.69	21.14	.69	28.13	.68	34.45	.68	39.92	.67	45.20	.67	50.29	.66	55.19
33	.70	23.02	.69	30.84	.69	37.52	.68	43.55	.68	49.37	.67	54.98	.67	60.39
34	.70	24.96	.70	33.65	.70	41.16	.69	47.75	.69	53.68	.68	60.28	.68	65.79
35	.71	27.21	.71	36.56	.70	44.45	.70	51.64	.69	58.60	.69	65.33	.68	71.82

Table 39. — Chestnut oak; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−1.19	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	−1.29	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	−1.39	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	−1.45	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	−1.49	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	−1.47	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	−1.40	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	−1.31	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	−1.14	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	− .91	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
21	.40	− .60	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
22	.40	− .21	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
23	.40	.27	.40	$ 0.38	.40	$ 0.48	.40	$ 0.56	.40	$ 0.65	.40	$ 0.73	.40	$ 0.82
24	.40	.63	.40	.86	.40	1.07	.40	1.27	.40	1.19	.40	1.67	.40	1.85
25	.40	.92	.40	1.26	.40	1.57	.40	1.86	.40	2.16	.40	2.45	.40	2.71
26	.40	1.12	.40	1.54	.40	1.91	.40	2.27	.40	2.62	.40	2.96	.40	3.30
27	.40	1.28	.40	1.74	.40	2.17	.40	2.57	.40	3.00	.40	3.36	.40	3.75
28	.40	1.41	.40	1.94	.40	2.41	.40	2.83	.40	3.28	.40	3.73	.40	4.13
29	.40	1.57	.40	2.14	.40	2.66	.40	3.15	.40	3.61	.40	4.11	.40	4.57
30	.40	1.72	.40	2.31	.40	2.88	.40	3.40	.40	3.91	.40	4.45	.40	4.96
31	.40	1.87	.40	2.53	.40	3.15	.40	3.71	.40	4.26	.40	4.86	.40	5.37
32	.40	2.03	.40	2.74	.40	3.40	.40	4.01	.40	4.61	.40	5.22	.40	5.82
33	.40	2.18	.40	2.96	.40	3.66	.40	4.32	.40	4.97	.40	5.62	.40	6.28
34	.40	2.34	.40	3.20	.40	3.97	.40	4.67	.40	5.34	.40	6.09	.40	6.75
35	.40	2.52	.40	3.43	.40	4.24	.40	5.00	.40	5.75	.40	6.51	.40	7.27

Table 40. — Red oak; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.93	$ 7.74	0.89	$ 10.08	0.86	$ 11.41	0.83	$ 12.40	0.79	$ 13.10	0.76	$ 13.11	0.73	—
17	.95	9.30	.91	12.23	.88	14.24	.85	15.50	.81	16.33	.78	16.62	.75	—
18	.96	11.32	.93	14.80	.90	17.28	.86	19.00	.83	20.21	.80	20.87	.76	$ 21.12
19	.98	13.52	.95	17.76	.92	20.83	.88	23.05	.85	24.56	.82	25.53	.78	26.04
20	1.00	15.98	.97	20.97	.94	24.68	.90	27.47	.87	29.32	.84	30.65	.80	31.47
21	1.02	18.73	.99	24.60	.95	29.10	.92	32.58	.89	35.26	.85	36.95	.82	37.39
22	1.04	21.77	1.01	28.70	.97	33.95	.94	38.10	.91	41.29	.87	43.42	.84	44.56
23	1.06	24.91	1.02	32.88	.99	39.16	.96	44.04	.92	47.80	.89	50.83	.86	53.15
24	1.08	28.59	1.04	37.46	1.01	44.32	.98	49.93	.94	55.17	.91	58.65	.88	60.94
25	1.10	32.23	1.06	42.11	1.03	50.21	1.00	56.41	.96	62.22	.93	66.64	.90	69.74
26	1.11	36.15	1.08	47.27	1.05	56.16	1.01	63.49	.98	69.83	.95	74.72	.91	78.67
27	1.13	40.16	1.10	52.10	1.07	62.27	1.03	70.22	1.00	78.17	.97	83.02	.93	87.87
28	1.15	44.05	1.12	58.27	1.08	69.15	1.05	77.73	1.02	85.74	.98	92.62	.95	97.40
29	1.17	48.98	1.14	64.06	1.10	76.30	1.07	86.67	1.04	94.70	1.00	102.63	.97	108.34
30	1.19	54.34	1.16	70.04	1.12	83.68	1.09	94.75	1.06	103.97	1.02	113.02	.99	119.70
31	1.21	59.61	1.17	77.53	1.14	92.59	1.11	104.35	1.07	114.76	1.04	124.92	1.01	131.54
32	1.23	65.06	1.19	84.61	1.16	101.17	1.13	114.28	1.09	125.94	1.06	136.15	1.03	144.91
33	1.25	70.69	1.21	92.61	1.18	110.05	1.14	124.57	1.11	137.54	1.08	148.96	1.04	158.82
34	1.26	76.49	1.23	100.88	1.20	120.57	1.16	136.51	1.13	149.56	1.10	163.42	1.06	173.25
35	1.28	83.21	1.25	109.41	1.22	130.06	1.18	147.54	1.15	163.25	1.12	177.19	1.08	189.38

Table 41. — Red oak; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.72	$ 2.96	0.70	$ 3.79	0.68	$ 4.40	0.66	$ 4.64	0.64	$ 4.68	—	—	—	—
15	.73	3.81	.71	4.92	.69	5.66	.67	6.09	.66	6.29	0.64	—	—	—
16	.74	4.76	.72	6.22	.71	7.08	.69	7.74	.67	8.24	.65	$ 8.31	0.63	—
17	.76	5.82	.74	7.68	.72	9.00	.70	9.87	.68	10.48	.66	10.77	.64	—
18	.77	7.18	.75	9.44	.73	11.10	.71	12.29	.69	13.19	.67	13.76	.65	$ 14.09
19	.78	8.69	.76	11.48	.74	13.56	.72	15.12	.70	16.26	.68	17.08	.66	17.62
20	.79	10.39	.77	13.71	.75	16.26	.73	18.24	.71	19.64	.69	20.75	.67	21.55
21	.80	12.29	.78	16.25	.76	19.36	.74	21.86	.72	23.87	.70	25.27	.69	25.87
22	.81	14.12	.79	19.13	.77	22.80	.75	25.79	.74	28.21	.72	29.96	.70	31.10
23	.82	16.63	.80	22.11	.79	26.51	.77	30.06	.75	32.91	.73	35.35	.71	37.37
24	.84	19.16	.82	25.27	.80	30.11	.78	34.18	.76	38.10	.74	40.89	.72	42.94
25	.85	21.63	.83	28.44	.81	34.15	.79	38.66	.77	42.99	.75	46.46	.73	49.12
26	.86	24.25	.84	31.91	.82	38.16	.80	43.45	.78	48.17	.76	52.00	.74	55.28
27	.87	26.91	.85	35.11	.83	42.24	.81	47.97	.79	53.80	.77	57.62	.75	61.55
28	.88	29.46	.86	39.20	.84	46.81	.82	52.97	.80	58.86	.78	64.09	.77	68.00
29	.89	32.71	.87	43.02	.85	51.55	.83	58.93	.82	64.85	.80	70.82	.78	75.39
30	.90	36.23	.88	46.95	.87	56.42	.85	64.28	.83	71.02	.81	77.76	.79	83.03
31	.92	39.69	.90	51.88	.88	62.30	.86	70.64	.84	78.19	.82	85.72	.80	90.96
32	.93	43.25	.91	56.53	.89	67.95	.87	77.21	.85	85.62	.83	93.19	.81	99.92
33	.94	46.92	.92	61.77	.90	73.79	.88	83.99	.86	93.30	.84	101.70	.82	109.21
34	.95	50.70	.93	67.18	.91	80.70	.89	91.86	.87	101.23	.85	111.31	.83	118.82
35	.96	55.08	.94	72.75	.92	86.91	.90	99.10	.88	110.27	.86	120.43	.85	129.56

Table 42. — Red oak; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.56	$ 0.32	0.55	$ 0.30	—	—	—	—	—	—	—	—	—	—
12	.57	.56	.56	.60	0.54	—	—	—	—	—	—	—	—	—
13	.58	.87	.56	1.01	.55	—	0.53	—	—	—	—	—	—	—
14	.58	1.26	.57	1.49	.55	$ 1.57	.54	—	0.52	—	—	—	—	—
15	.59	1.74	.57	2.13	.56	2.28	.54	—	.53	—	0.51	—	—	—
16	.59	2.31	.58	2.89	.56	3.12	.55	$ 3.19	.53	—	.52	—	0.50	—
17	.60	2.96	.58	3.77	.57	4.24	.55	4.42	.54	—	.52	—	.51	—
18	.61	3.80	.59	4.85	.57	5.51	.56	5.86	.54	$ 6.00	.53	—	.51	—
19	.61	4.74	.60	6.12	.58	7.02	.57	7.58	.55	7.85	.54	$ 7.88	.52	—
20	.62	5.82	.60	7.53	.59	8.72	.57	9.52	.56	9.95	.54	10.13	.53	—
21	.62	7.05	.61	9.16	.59	10.70	.58	11.80	.56	12.56	.55	12.91	.53	—
22	.63	8.44	.61	11.03	.60	12.91	.58	14.33	.57	15.33	.55	15.89	.54	$ 16.03
23	.63	9.91	.62	12.99	.60	15.35	.59	17.11	.57	18.40	.56	19.35	.54	19.97
24	.64	11.50	.62	14.98	.61	17.61	.59	19.69	.58	21.57	.56	22.72	.55	23.35
25	.65	13.03	.63	16.94	.62	20.07	.60	22.39	.58	24.51	.57	26.02	.55	26.97
26	.65	14.60	.64	19.00	.62	22.43	.61	25.19	.59	27.50	.58	29.18	.56	30.44
27	.66	16.18	.64	20.87	.63	24.79	.61	27.77	.60	30.69	.58	32.32	.57	33.90
28	.66	17.67	.65	23.24	.63	27.41	.62	30.60	.60	33.51	.59	35.90	.57	37.40
29	.67	19.56	.65	25.44	.64	30.12	.62	33.98	.61	36.85	.59	39.61	.58	41.43
30	.67	21.60	.66	27.69	.64	32.88	.63	36.97	.61	40.27	.60	43.41	.58	45.55
31	.68	23.60	.66	30.52	.65	36.22	.63	40.54	.62	44.25	.60	47.77	.59	49.84
32	.69	25.65	.67	33.17	.66	39.41	.64	44.21	.63	48.35	.61	51.84	.59	54.66
33	.69	27.76	.68	36.16	.66	42.69	.65	47.99	.63	52.59	.62	56.48	.60	59.66
34	.70	29.93	.68	39.23	.67	46.59	.65	52.38	.64	56.95	.62	61.72	.61	64.83
35	.70	32.43	.69	42.39	.67	50.07	.66	56.40	.64	61.93	.63	66.67	.61	70.60

Table 43. — Red oak; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−0.90	0.40	—	0.40	—	0.40	—	0.40	—	—	—	0.40	—
12	.40	−.95	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	−.99	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	−.97	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	−.94	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	−.84	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	−.69	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	−.50	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	−.23	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	.11	.40	$ 0.16	.40	$ 0.20	.40	$ 0.23	.40	$ 0.27	.40	$ 0.30	.40	$ 0.33
21	.40	.53	.40	.74	.40	.93	.40	1.10	.40	1.27	.40	1.43	.40	1.56
22	.40	1.04	.40	1.45	.40	1.81	.40	2.15	.40	2.47	.40	2.77	.40	3.05
23	.40	1.64	.40	2.28	.40	2.85	.40	3.38	.40	3.89	.40	4.39	.40	4.90
24	.40	2.14	.40	2.94	.40	3.65	.40	4.33	.40	5.06	.40	5.69	.40	6.29
25	.40	2.57	.40	3.52	.40	4.39	.40	5.19	.40	6.03	.40	6.83	.40	7.57
26	.40	2.92	.40	4.00	.40	4.97	.40	5.90	.40	6.82	.40	7.70	.40	8.58
27	.40	3.23	.40	4.38	.40	5.47	.40	6.47	.40	7.56	.40	8.46	.40	9.45
28	.40	3.50	.40	4.82	.40	5.98	.40	7.03	.40	8.14	.40	9.25	.40	10.25
29	.40	3.84	.40	5.23	.40	6.50	.40	7.71	.40	8.83	.40	10.05	.40	11.16
30	.40	4.18	.40	5.61	.40	6.99	.40	8.26	.40	9.19	.40	10.81	.40	12.04
31	.40	4.51	.40	6.10	.40	7.59	.40	8.93	.40	10.26	.40	11.70	.40	12.93
32	.40	4.85	.40	6.55	.40	8.14	.40	9.59	.40	11.03	.40	12.48	.40	13.92
33	.40	5.18	.40	7.04	.40	8.70	.40	10.26	.40	11.81	.40	13.36	.40	14.92
34	.40	5.52	.40	7.55	.40	9.37	.40	11.03	.40	12.60	.40	14.37	.40	15.93
35	.40	5.91	.40	8.05	.40	9.94	.40	11.72	.40	13.49	.40	15.27	.40	17.05

Table 44. — White oak; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.90	$ 5.86	0.86	$ 7.44	0.82	$ 8.17	0.79	$ 8.56	0.75	$ 8.64	0.71	—	0.68	—
17	.92	7.26	.89	9.35	.85	10.64	.81	11.25	.78	11.45	.74	—	.70	—
18	.95	9.08	.91	11.67	.88	13.36	.84	14.36	.80	14.87	.76	—	.73	—
19	.98	11.10	.94	14.37	.90	16.59	.86	18.02	.83	18.79	.79	$ 19.03	.75	—
20	1.00	13.39	.96	17.36	.93	20.16	.89	22.10	.85	23.17	.81	23.73	.78	$ 23.76
21	1.03	15.97	.99	20.77	.95	24.29	.91	26.86	.88	28.65	.84	29.52	.80	29.29
22	1.05	18.85	1.01	24.65	.98	28.89	.94	32.08	.90	34.35	.87	35.63	.83	35.99
23	1.08	21.88	1.04	28.68	1.00	33.89	.97	37.77	.93	40.59	.89	42.68	.85	44.04
24	1.10	25.41	1.07	33.09	1.03	38.89	.99	43.47	.95	47.62	.92	50.14	.88	51.53
25	1.13	28.95	1.09	37.62	1.05	44.58	1.02	49.76	.98	54.47	.94	57.85	.90	59.98
26	1.15	32.77	1.12	42.65	1.08	50.40	1.04	56.64	1.00	61.89	.97	65.74	.93	68.65
27	1.18	36.72	1.14	47.43	1.10	56.43	1.07	63.30	1.03	70.06	.99	73.94	.96	77.69
28	1.20	40.60	1.17	53.50	1.13	63.22	1.09	70.74	1.06	77.64	1.02	83.40	.98	87.16
29	1.23	45.49	1.19	59.29	1.16	70.35	1.12	79.59	1.08	86.58	1.04	93.38	1.01	98.03
30	1.26	50.82	1.22	65.31	1.18	77.78	1.14	87.76	1.11	95.92	1.07	103.81	1.03	109.43
31	1.28	56.13	1.24	72.81	1.21	86.71	1.17	97.41	1.13	106.77	1.10	115.79	1.06	121.42
32	1.31	61.66	1.27	80.01	1.23	95.42	1.19	107.50	1.16	118.11	1.12	127.27	1.08	134.97
33	1.33	67.41	1.29	88.13	1.26	104.50	1.22	118.01	1.18	129.96	1.15	140.35	1.11	149.18
34	1.36	73.37	1.32	96.59	1.28	115.22	1.25	130.19	1.21	142.32	1.17	155.14	1.13	164.04
35	1.38	80.26	1.35	105.37	1.31	125.06	1.27	141.61	1.23	156.40	1.20	169.41	1.16	180.66

Table 45. — White oak; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.60	$ 0.76	0.59	$ 0.85	0.57	—	0.56	—	0.54	—	—	—	—	—
15	.62	1.36	.61	1.64	.59	$ 1.73	.58	—	.56	—	0.55	—	—	—
16	.64	2.09	.63	2.63	.61	2.86	.60	$ 2.97	.59	—	.57	—	0.56	—
17	.66	2.95	.65	3.82	.63	4.37	.62	4.66	.61	$ 4.79	.59	—	.58	—
18	.68	4.06	.67	5.28	.66	6.13	.64	6.70	.63	7.08	.61	$ 7.25	.60	—
19	.70	5.34	.69	7.03	.68	8.26	.66	9.17	.65	9.80	.63	10.22	.62	$ 10.47
20	.73	6.84	.71	9.03	.70	10.70	.68	12.00	.67	12.93	.65	13.65	.64	14.18
21	.75	8.57	.73	11.36	.72	13.57	.70	15.36	.69	16.83	.68	17.89	.66	18.39
22	.77	10.54	.75	14.05	.74	16.82	.72	19.13	.71	21.04	.70	22.49	.68	23.51
23	.79	12.66	.77	16.93	.76	20.43	.75	23.31	.73	25.72	.72	27.84	.70	29.69
24	.81	15.06	.79	19.99	.78	24.00	.77	27.45	.75	30.85	.74	33.41	.72	35.44
25	.83	17.47	.82	23.15	.80	28.00	.79	31.97	.77	35.88	.76	39.16	.75	41.85
26	.85	20.06	.84	26.60	.82	32.08	.81	36.86	.79	41.26	.78	45.00	.77	48.39
27	.87	22.75	.86	29.92	.84	36.32	.83	41.63	.82	47.17	.80	51.08	.79	55.20
28	.89	25.41	.88	34.10	.86	41.09	.85	46.95	.84	52.73	.82	58.06	.81	62.36
29	.91	28.74	.90	38.14	.89	46.13	.87	53.27	.86	59.26	.84	65.48	.83	70.57
30	.93	32.40	.92	42.37	.91	51.41	.89	59.19	.88	66.12	.86	73.26	.85	79.22
31	.96	36.08	.94	47 61	.93	57.75	.91	66.17	.90	74.08	.88	82.19	.87	88.35
32	.98	39.94	.96	52.70	.95	64.00	.93	73.50	.92	82.45	.91	90.84	.89	98.67
33	1.00	43.97	.98	58.46	.97	70.55	.95	81.19	.94	91.23	.93	100.68	.91	109.53
34	1.02	48.19	1.00	64.48	.99	78.26	.98	90.08	.96	100.43	.95	111.81	.93	120.93
35	1.04	53.05	1.02	70.77	1.01	85.44	1.00	98.51	.98	110.91	.97	122.63	.95	133.68

Table 46. — White oak; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.50	$—0.50	0.50	—	—	—	—	—	—	—	—	—	—	—
12	.51	— .38	.51	—	0.50	—	—	—	—	—	—	—	—	—
13	.53	— .19	.52	—	.52	—	0.51	—	—	—	—	—	—	—
14	.54	.09	.53	—	.53	—	.52	—	0.52	—	—	—	—	—
15	.55	.46	.55	$ 0.54	.54	$ 0.56	.54	—	.53	—	0.53	—	—	—
16	.56	.93	.56	1.19	.55	1.32	.55	$ 1.41	.54	$ 1.46	.54	—	0.53	—
17	.58	1.50	.57	1.98	.56	2.33	.56	2.57	.55	2.74	.55	$ 2.83	.54	—
18	.59	2.23	.58	2.97	.58	3.54	.57	3.98	.57	4.35	.56	4.63	.56	$ 4.85
19	.60	3.10	.59	4.17	.59	5.01	.58	5.71	.58	6.28	.57	6.77	.57	7.20
20	.61	4.12	.61	5.55	.60	6.27	.60	7.72	.59	8.53	.59	9.26	.58	9.92
21	.62	5.31	.62	7.17	.61	8.73	.61	10.10	.60	11.32	.60	12.34	.59	13.03
22	.64	6.68	.63	9.05	.62	11.04	.62	12.79	.61	14.37	.61	15.70	.60	16.81
23	.65	8.17	.64	11.09	.64	13.61	.63	15.81	.63	17.77	.62	19.63	.62	21.38
24	.66	9.78	.65	13.18	.65	16.07	.64	18.68	.64	21.36	.63	23.56	.63	25.48
25	.67	11.38	.67	15.28	.66	18.75	.66	21.74	.65	24.79	.65	27.52	.64	29.94
26	.68	13.04	.68	17.52	.67	21.41	.67	24.96	.66	28.37	.66	31.43	.65	34.37
27	.70	14.74	.69	19.63	.69	24.13	.68	28.04	.67	32.23	.67	35.42	.66	38.90
28	.71	16.40	.70	22.27	.70	27.17	.69	31.45	.69	35.80	.68	39.99	.68	43.59
29	.72	18.49	.71	24.81	.71	30.37	.70	35.51	.70	40.01	.69	44.80	.69	48.97
30	.73	20.77	.73	27.46	.72	33.69	.72	39.25	.71	44.38	.71	49.81	.70	54.58
31	.74	23.06	.74	30.74	.73	37.69	.73	43.68	.72	49.47	.72	55.56	.71	60.49
32	.76	25.45	.75	33.91	.75	41.61	.74	48.31	.73	54.79	.73	61.09	.72	67.15
33	.77	27.94	.76	37.50	.76	45.71	.75	53.14	.75	60.36	.74	67.35	.74	74.13
34	.78	30.54	.77	41.24	.77	50.53	.76	58.74	.76	66.17	.75	74.45	.75	81.42
35	.79	33.53	.79	45.14	.78	54.99	.78	64.01	.77	72.78	.77	81.30	.76	89.58

Table 47. — White oak; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$−1.19	.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	−1.29	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	−1.39	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	−1.45	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	−1.49	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	−1.47	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	−1.40	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
18	.40	−1.31	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
19	.40	−1.14	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
20	.40	− .91	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
21	.40	− .60	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
22	.40	− .21	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
23	.40	.27	.40	$ 0.38	.40	$ 0.48	.40	$ 0.56	.40	$ 0.65	.40	$ 0.73	.40	$ 0.82
24	.40	.63	.40	.86	.40	1.07	.40	1.27	.40	1.49	.40	1.67	.40	1.85
25	.40	.92	.40	1.26	.40	1.57	.40	1.86	.40	2.16	.40	2.45	.40	2.71
26	.40	1.12	.40	1.54	.40	1.91	.40	2.27	.40	2.62	.40	2.96	.40	3.30
27	.40	1.28	.40	1.74	.40	2.17	.40	2.57	.40	3.00	.40	3.36	.40	3.75
28	.40	1.41	.40	1.94	.40	2.41	.40	2.83	.40	3.28	.40	3.73	.40	4.13
29	.40	1.57	.40	2.14	.40	2.66	.40	3.15	.40	3.61	.40	4.11	.40	4.56
30	.40	1.72	.40	2.31	.40	2.88	.40	3.40	.40	3.91	.40	4.45	.40	4.96
31	.40	1.87	.40	2.53	.40	3.15	.40	3.71	.40	4.26	.40	4.86	.40	5.37
32	.40	2.03	.40	2.74	.40	3.40	.40	4.01	.40	4.61	.40	5.21	.40	5.82
33	.40	2.18	.40	2.96	.40	3.66	.40	4.32	.40	4.97	.40	5.62	.40	6.28
34	.40	2.34	.40	3.20	.40	3.97	.40	4.67	.40	5.34	.40	6.09	.40	6.75
35	.40	2.52	.40	3.43	.40	4.24	.40	4.99	.40	5.75	.40	6.51	.40	7.27

Table 48. — Yellow-poplar; butt log grade I

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
16	0.75	$ 5.97	0.74	$ 8.19	0.73	$ 9.83	0.73	$ 11.40	0.72	$ 12.94	0.71	$ 14.05	0.71	$ 14.80
17	.76	7.27	.76	10.05	.75	12.36	.74	14.28	.74	16.07	.73	17.61	.72	18.69
18	.78	8.97	.77	12.28	.76	15.09	.76	17.54	.75	19.84	.74	21.91	.74	23.90
19	.79	10.83	.79	14.87	.78	18.29	.77	21.32	.77	24.04	.76	26.60	.75	29.05
20	.81	12.93	.80	17.68	.80	21.78	.79	25.45	.78	28.64	.78	31.72	.77	34.68
21	.82	15.28	.82	20.89	.81	25.79	.80	30.23	.80	34.37	.79	38.01	.78	40.79
22	.84	17.90	.83	24.51	.83	30.20	.82	35.39	.81	40.19	.81	44.44	.80	48.17
23	.85	20.63	.85	28.24	.84	34.95	.83	40.96	.83	46.15	.82	51.80	.82	56.98
24	.87	23.79	.86	32.28	.86	29.64	.85	46.45	.84	53.53	.84	59.53	.83	64.92
25	.89	26.92	.88	36.39	.87	44.97	.87	52.48	.86	60.27	.85	67.40	.85	73.89
26	.90	30.28	.89	40.93	.89	50.34	.88	59.04	.87	67.53	.87	75.34	.86	82.94
27	.92	33.72	.91	45.17	.90	55.85	.90	65.28	.89	75.48	.88	83.47	.88	92.23
28	.93	37.06	.93	50.59	.92	62.04	.91	72.21	.91	82.66	.90	92.86	.89	101.82
29	.95	41.29	.94	55.68	.93	68.48	.93	80.48	.92	91.16	.91	102.63	.91	112.81
30	.96	45.89	.96	60.94	.95	75.14	.94	87.95	.94	99.94	.93	112.73	.92	124.18
31	.98	50.43	.97	67.53	.97	83.16	.96	96.81	.95	110.16	.95	124.31	.94	135.99
32	.99	55.13	.99	73.78	.98	90.90	.97	105.98	.97	120.74	.96	135.19	.95	149.33
33	1.01	59.99	1.00	80.83	1.00	98.91	.99	115.47	.98	131.70	.98	147.59	.97	163.15
34	1.03	65.01	1.02	88.12	1.01	108.39	1.01	126.48	1.00	143.03	.99	161.59	.99	177.45
35	1.04	70.82	1.03	95.66	1.03	116.96	1.02	136.65	1.01	155.95	1.01	174.88	1.00	193.43

Table 49. — Yellow-poplar; butt log grade 2

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
14	0.70	$ 3.57	0.68	$ 4.45	0.65	$ 5.01	0.62	$ 5.07	0.59	—	—	—	—	—
15	.71	4.49	.68	5.65	.66	6.32	.63	6.54	.60	—	0.57	—	—	—
16	.72	5.51	.69	7.03	.67	7.76	.64	8.19	.61	$ 8.34	.58	—	0.56	—
17	.73	6.63	.70	8.55	.67	9.74	.65	10.32	.62	10.52	.59	—	.56	—
18	.74	8.08	.71	10.37	.68	11.86	.66	12.73	.63	13.15	.60	—	.57	—
19	.75	9.65	.72	12.47	.69	14.34	.66	15.53	.64	16.12	.61	$ 16.24	.58	—
20	.76	11.42	.73	14.74	.70	17.05	.67	18.59	.65	19.37	.62	19.69	.59	—
21	.76	13.38	.74	17.33	.71	20.16	.68	22.11	.65	23.41	.63	23.91	.60	—
22	.77	15.57	.75	20.24	.72	23.57	.69	25.99	.66	27.60	.64	28.35	.61	—
23	.78	17.82	.75	23.22	.73	27.25	.70	30.14	.67	32.11	.64	33.41	.62	$ 34.06
24	.79	20.41	.76	26.40	.74	30.79	.71	34.11	.68	37.04	.65	38.57	.63	39.14
25	.80	22.91	.77	29.57	.74	31.76	.72	38.45	.69	41.67	.66	43.74	.63	44.74
26	.81	25.57	.78	33.02	.75	38.69	.73	43.06	.70	46.55	.67	48.83	.64	50.28
27	.82	28.25	.79	36.18	.76	42.65	.73	47.37	.71	51.83	.68	53.98	.65	55.89
28	.83	30.80	.80	40.24	.77	47.09	.74	52.13	.72	56.53	.69	59.90	.66	61.64
29	.84	34.06	.81	43.99	.78	51.68	.75	57.81	.72	62.11	.70	66.04	.67	68.23
30	.84	37.58	.82	47.84	.79	56.37	.76	62.87	.73	67.83	.71	72.35	.68	75.01
31	.85	41.01	.83	52.68	.80	62.05	.77	68.88	.74	74.49	.71	79.58	.69	82.06
32	.86	44.54	.83	57.20	.81	67.16	.78	75.07	.75	81.36	.72	86.34	.70	90.01
33	.87	48.15	.84	62.30	.82	73.03	.79	81.44	.76	88.44	.73	94.04	.71	98.24
34	.88	51.86	.85	67.55	.82	79.64	.80	88.84	.77	95.75	.74	102.74	.71	106.75
35	.89	56.16	.86	72.93	.83	85.53	.81	95.60	.78	104.07	.75	110.95	.72	116.24

Table 50. — Yellow-poplar; butt log grade 3

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.50	$ 0.21	0.49	—	—	—	—	—	—	—	—	—	—	—
12	.51	.47	.50	$ 0.51	0.49	—	—	—	—	—	—	—	—	—
13	.52	.81	.51	1.01	.50	$ 1.06	0.49	—	—	—	—	—	—	—
14	.53	1.24	.52	1.57	.51	1.79	.50	$ 1.84	0.49	—	—	—	—	—
15	.54	1.80	.53	2.31	.52	2.65	.51	2.83	.50	$ 2.90	0.50	—	—	—
16	.55	2.45	.54	3.21	.53	3.66	.52	4.01	.51	4.28	.50	$ 4.34	0.50	—
17	.56	3.20	.55	4.25	.54	5.01	.53	5.54	.52	5.93	.51	6.16	.51	$ 6.16
18	.57	4.17	.56	5.52	.55	6.55	.54	7.33	.53	7.96	.52	8.42	.52	8.76
19	.58	5.26	.57	7.03	.56	8.39	.55	9.47	.54	10.32	.53	11.00	.52	11.55
20	.59	6.53	.58	8.71	.57	10.45	.56	11.88	.55	12.97	.54	13.92	.54	14.72
21	.60	7.97	.59	10.66	.58	12.85	.57	14.70	.56	16.29	.55	17.53	.54	18.27
22	.61	9.60	.60	12.89	.59	15.55	.58	17.83	.57	19.79	.56	21.36	.55	22.57
23	.62	11.35	.61	15.25	.60	18.52	.59	21.28	.58	23.65	.57	25.80	.56	27.75
24	.62	13.27	.62	17.71	.61	21.36	.60	24.58	.59	27.78	.58	30.29	.57	32.35
25	.63	15.16	.63	20.17	.62	24.51	.61	28.11	.60	31.70	.59	34.79	.58	37.40
26	.64	17.14	.63	22.81	.63	27.62	.62	31.86	.61	35.81	.60	39.24	.59	42.39
27	.65	19.16	.64	25.28	.64	30.78	.63	35.40	.62	40.26	.61	43.76	.60	47.48
28	.66	21.11	.65	28.40	.64	34.31	.64	39.32	.63	44.29	.62	48.93	.61	52.73
29	.67	23.57	.66	31.35	.65	38.00	.65	43.99	.64	49.06	.63	54.31	.62	58.74
30	.68	26.25	.67	34.39	.66	41.81	.65	48.23	.65	53.98	.64	59.94	.63	64.97
31	.69	28.90	.68	38.19	.67	46.40	.66	53.25	.66	59.71	.65	66.37	.64	71.47
32	.70	31.65	.69	41.82	.68	50.84	.67	58.46	.67	65.67	.66	72.45	.65	78.82
33	.71	34.50	.70	45.91	.69	55.45	.68	63.88	.67	71.85	.67	79.38	.66	86.46
34	.72	37.45	.71	50.15	.70	60.91	.69	70.15	.68	78.27	.68	87.21	.67	94.40
35	.73	40.86	.72	54.53	.71	65.86	.70	75.98	.69	85.58	.68	94.68	.68	103.27

Table 51. — Yellow-poplar; butt log grade 4

Dbh (inches)	Merchantable height to an 8-inch dib top (feet)													
	16		24		32		40		48		56		64	
	TQI	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*	*TQI*	*TVCS*
11	0.40	$—0.62	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—	0.40	—
12	.40	— .61	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
13	.40	— .58	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
14	.40	— .50	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
15	.40	— .38	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
16	.40	— .21	.40	—	.40	—	.40	—	.40	—	.40	—	.40	—
17	.40	.02	.40	$ 0.03	.40	$ 0.04	.40	$ 0.04	.40	$ 0.05	.40	$ 0.05	.40	$ 0.06
18	.40	.31	.40	.44	.40	.55	.40	.65	.40	.75	.40	.84	.40	.93
19	.40	.68	.40	.95	.40	1.19	.40	1.41	.40	1.62	.40	1.82	.40	2.02
20	.40	1.13	.40	1.57	.40	1.97	.40	2.33	.40	2.67	.40	3.00	.40	3.33
21	.40	1.67	.40	2.31	.40	2.90	.40	3.44	.40	3.97	.40	4.46	.40	4.86
22	.40	2.30	.40	3.19	.40	3.98	.40	4.73	.40	5.44	.40	6.10	.40	6.71
23	.40	3.01	.40	4.17	.40	5.23	.40	6.20	.40	7.13	.40	8.05	.40	8.98
24	.40	3.65	.40	5.02	.40	6.23	.40	7.39	.40	8.63	.40	9.71	.40	10.73
25	.40	4.22	.40	5.77	.40	7.21	.40	8.52	.40	9.90	.40	11.21	.40	12.43
26	.40	4.72	.40	6.46	.40	8.03	.40	9.53	.40	11.02	.40	12.44	.40	13.86
27	.40	5.18	.40	7.02	.40	8.77	.40	10.37	.40	12.12	.40	13.56	.40	15.15
28	.40	5.59	.40	7.70	.40	9.55	.40	11.23	.40	13.00	.40	14.77	.40	16.37
29	.40	6.10	.40	8.32	.40	10.34	.40	12.27	.40	14.05	.40	15.99	.40	17.76
30	.40	6.64	.40	8.91	.40	11.10	.40	13.12	.40	15.07	.40	17.17	.40	19.12
31	.40	7.15	.40	9.67	.40	12.03	.40	14.15	.40	16.26	.40	18.54	.40	20.49
32	.40	7.67	.40	10.36	.40	12.88	.40	15.17	.40	17.45	.40	19.73	.40	22.02
33	.40	8.18	.40	11.12	.40	13.74	.40	16.20	.40	18.65	.40	21.10	.40	23.56
34	.40	8.70	.40	11.90	.40	14.77	.40	17.39	.40	19.86	.40	22.65	.40	25.11
35	.40	9.30	.40	12.67	.40	15.64	.40	18.43	.40	21.23	.40	24.03	.40	26.83

Table 52.—Conversion costs for hardwood trees

Dbh	Cost per M board feet		
(inches)	$60.00 level	$70.00 level	$80.00 level
11	$70.84	$80.84	$90.84
12	68.67	78.67	88.67
13	66.50	76.50	86.50
14	64.34	74.34	84.34
15	62.17	72.17	82.17
16	60.00	70.00	80.00
17	57.83	67.83	77.83
18	55.67	65.67	75.67
19	53.50	63.50	73.50
20	51.33	61.33	71.33
21	49.17	59.17	69.17
22	47.00	57.00	67.00
23	44.80	54.80	64.80
24	43.50	53.50	63.50
25	42.65	52.65	62.65
26	42.25	52.25	62.25
27	42.05	52.05	62.05
28	41.95	51.95	61.95
29	41.85	51.85	61.85
30	41.80	51.80	61.80
31	41.74	51.74	61.74
32	41.69	51.69	61.69
33	41.64	51.64	61.64
34	41.59	51.59	61.59
35	41.54	51.54	61.54

Table 53.—Gross volume in board feet (International ¼-inch rule)

Dbh (inches)	Merchantable height in feet							
	8	16	24	32	40	48	56	64
8	15	24	35	46	—	—	—	—
9	18	32	44	54	63	—	—	—
10	21	39	54	68	76	81	—	—
11	25	48	68	82	91	98	—	—
12	30	57	80	100	114	124	130	—
13	36	68	96	118	134	149	161	171
14	42	79	110	140	163	184	194	205
15	50	92	128	160	188	214	232	250
16	59	105	147	180	213	247	274	295
17	66	118	166	208	245	281	314	340
18	74	135	188	235	278	320	360	400
19	83	152	212	265	314	360	405	450
20	92	170	236	295	350	400	450	500
21	102	189	262	328	390	450	505	550
22	112	209	290	362	430	495	555	610
23	122	228	316	396	470	540	610	680
24	133	252	346	430	510	595	670	740
25	145	275	376	470	555	645	730	810
26	158	300	410	510	605	700	790	880
27	172	325	440	550	650	760	850	950
28	187	348	480	595	700	810	920	1,020
29	203	378	515	640	760	870	990	1,100
30	220	410	550	685	810	930	1,060	1,180
31	237	440	595	740	870	1,000	1,140	1,260
32	254	470	635	790	930	1,070	1,210	1,350
33	270	500	680	840	990	1,140	1,290	1,440
34	291	530	725	900	1,060	1,210	1,380	1,530
35	311	565	770	950	1,120	1,290	1,460	1,630

Source: Composite volume tables for timber and their application in the Lake States, by S. R. Gevorkiantz and L. P. Olsen. USDA Tech. Bull. 1104, 1955.

APPENDIX B

COMPUTER PROGRAM AND DOCUMENTATION

Tree value conversion standards may be computed or adjusted very easily by computer using the program given here. This program, written in Fortran IV, was developed primarily for simplicity of use. It is quite flexible in that (1) you can punch the data deck in any format you want and use any two-digit species code; (2) you have the option of using whatever conversion costs and lumber prices best suit your particular conditions; and (3) you have a variety of options for different printouts.

The program was tested on an IBM 370/158; however, it should work on most computers that accept standard Fortran. The Job Control Language (JCL) cards are not listed here with the program because they differ for different computer installations. Complete instructions for the user are included as comment cards.

The program was tested with data from a 1-acre sawtimber stand of upland oak in southeastern Ohio. Figures 2 through 8 illustrate the type of computer output one would get if he ordered the conversion value of sawtimber printed by species, grade, and dbh class. This information is given in figure 6. Figures 4 and 5 follow the same general form; Figure 4 gives the number of sawtimber trees while Figure 5 illustrates the board-foot volume.

Figure 7 illustrates the form of summary that can be printed when the user requests it. This is a summary over all dbh classes of the number of trees, board-foot volume, and conversion value by grade and species. Figure 8 is similar except that the summary is over all species and shows the same type of information by 2-inch diameter classes.

Figure 2 illustrates part of the listing of individual sawtimber trees from our 1-acre test stand. For each sawtimber tree in the stand, it shows both measured and computed information, such as TQI, board-foot volume, and TVCS. The user may suppress the printing of this list if he so desires.

Figure 3 shows the list of individual trees in the test stand that did not qualify for inclusion in the sawtimber list. There are four reasons why individual trees may appear on this list: (1) tree diameter is less than sawtimber size (11.0 inches dbh); (2) no merchantable height is recorded for the tree or its merchantable height exceeds 96 feet, which may indicate a recording error; (3) no log grade is assigned to the tree or it is not one of the standard log grades 1, 2, or 3; or (4) the tree species is not one of the 12 species for which we have developed tree value conversion standards. This listing of excluded trees could be useful in editing the data for possible punching or recording errors. Printing of this list may also be suppressed if the user so desires.

There is one minor discrepancy between the values one obtains with the computer and those given by the desk calculator and table. This is because different methods were used to determine the board-foot volume of the trees. With the desk calculator, board-foot volume is determined by 1-inch dbh classes and 8-foot log classes, using the composite gross volume table (International ¼-inch rule) by Gevorkiantz and Olsen (1955). In the computer program we use a volume equation derived by Beers (1964). The equation is more flexible and better suited to computer computations, and it has the added advantage that dbh may be specified to the nearest 0.1 inch, rather than to the nearest inch. In his paper Beers discusses the size of the differences between the volumes in the original table and those given by his equation.

TQI values and conversion costs are also computed to the nearest 0.1 inch dbh rather than by 1-inch classes as they were in the tables.

As part of our test, we compared board-foot volume and tree value conversion estimates given by the desk calculator with those given by the computer program, using data from the 1-acre test stand. Total board-foot volume of sawtimber, using the composite table, was 11,147 board feet, compared to 11,124 board feet by equation; a difference of only 0.2 percent. The desk calculator and table gave a total tree value conversion of $442.21, compared to $440.97 for the computer program; a difference of $1.24 which is 0.3 percent. Estimates for individual trees will differ more, of course, but generally the total stand volumes and value conversions obtained by the two methods are very close.

NOTE: The program reproduced here is available on punched cards from the authors. Address requests to Project 4202, Northeastern Forest Experiment Station, P.O. Box 365, Delaware, Ohio 43015.

```
C
C    *******************************************************************************************
C                     PROGRAM TVCS   ---   TREE VALUE CONVERSION STANDARDS
C
C
C   PURPOSE :
C   ---------
C
C
C      THIS PROGRAM IS DESIGNED TO COMPUTE AND TABULATE THE INDIVIDUAL
C      SAWTIMBER VOLUME AND VALUE FOR EACH OF 12 TREE SPECIES.  THE BASIC
C      CONCEPTS AND TECHNIQUES USED IN DEVELOPING THE TREE VALUE CONVERSION
C      STANDARDS REPORTED IN THIS RESEARCH PAPER ARE USED IN THE COMPUTER
C      PROGRAM, AND THE USER SHOULD BE FAMILAR WITH THESE TECHNIQUES.
C      THE SAME TECHNIQUES PROBABLY COULD BE APPLIED TO OTHER HARDWOOD SPECIES,
C      BUT THE BASIC RESEARCH NEEDED TO DEVELOP THE REGRESSION COEFFICIENTS IN
C      THE TOT EQUATIONS HAS NOT BEEN COMPLETED.
C      THE USER HAS OPTIONS TO USE THE STANDARD CONVERSION COSTS AND
C      PRICES OF NO 1 COMMON LBR AS GIVEN IN THIS PAPER, OR
C      HE MAY USE HIS OWN CONVERSION COSTS AND LBR PRICE DATA.
C
C
C   TYPE OF STAND DATA NECESSARY FOR PROGRAM OPERATION:
C
C      THE USER NEEDS A DECK OF DATA CARDS WITH THE FOLLOWING DATA
C      PUNCHED ON A CARD FOR EACH SAWTIMBER TREE IN THE STAND:
C
C
C      1.  SPECIES CODE NUMBER
C
C                     SPECIES MAY BE CODED USING ANY TWO-DIGIT NUMBER FROM
C                     1 THRU 99.  SEE INSTRUCTIONS UNDER USER-SPECIFIED
C                     OPTIONS CARD 2.
C
C      2. DIAMETER BREAST HEIGHT
C
C                     IT IS PREFERABLE TO RECORD DIAMETER TO THE NEAREST
C                     0.1 INCH.  HOWEVER, THE NEAREST ONE OR TWO INCHES
C                     WOULD NOT AFFECT THE OPERATION OF THE PROGRAM.
C                     THE PROGRAM WILL LIST TREES SMALLER THAN 11 INCHES DBH
C                     IN A DIFFERENT LIST FROM THE SAWTIMBER TREES.
C
C      3. U.S. FOREST SERVICE STANDARD LOG GRADES FOR HARDWOOD FACTORY LUMBER.
C
C                     BUTT LOG GRADES 1, 2, OR 3.  ALL TREES WITH LOG GRADES
C                     OTHER THAN THESE WILL BE LISTED IN A DIFFERENT LIST
C                     FROM THE SAWTIMBER TREES.
C
C      4. MERCHANTABLE HEIGHT TO AN 8-INCH VARIABLE TOP DIAMETER INSIDE
C         BARK, IN FEET.
C
C                     MERCHANTABLE HEIGHT IS RECORDED IN FEET, AND USUALLY
C                     THIS HEIGHT IS RELATED TO MULTIPLES OF 8 FOOT LOG LENGTHS.
C                     I.E.  16, 24, 32, 40, 48, 56  ETC.  HOWEVER, THE PROGRAM
C                     IS WRITTEN TO ACCEPT AND USE ANY MERCHANTABLE HEIGHT
C                     BETWEEN 1 AND 96 FEET.
C                     TREES THAT HAVE LESS THAN 1 FOOT OR MORE THAN 96 FEET
C                     MERCHANTABLE HEIGHT WILL BE LISTED SEPARATELY FROM
C                     THE SAWTIMBER TREES.
C
C
C         IN CASE DATA ARE NOT ALREADY PUNCHED WE SUGGEST PUNCHING AS
```

```
C         SHOWN BELOW UNDER CARD 1 OF THE USER-SPECIFIED OPTIONS SECTION.
C         THIS SECTION ALSO GIVES INSTRUCTIONS ON WHAT TO DO IF DATA ARE
C         ALREADY PUNCHED IN SOME DIFFERENT FORMAT.
C
C  USER-SPECIFIED OPTIONS:
C
C         ALL THE INSTRUCTIONS FOR USING THIS PROGRAM ARE INCLUDED HERE.
C         SEVEN CARDS PRECEEDING THE STAND DATA DECK ARE MANDATORY.  THEY ARE
C         USED TO SPECIFY THE VARIOUS OPTIONS AND ALL SEVEN CARDS MUST BE
C         PRESENT, ALTHOUGH ALL EXCEPT THE FORMAT CARD (CARD NO 1) COULD
C         BE BLANK.
C
C
C      CARD 1  (FORMAT CARD THAT SPECIFIES THE FORMAT OF THE  STAND DATA
C         DECK TO BE READ).  THIS CARD IS NEVER BLANK.
C
C         TO ILLUSTRATE HOW THE FORMAT CARD IS PUNCHED WE ARE SHOWING
C         BELOW AN EXAMPLE OF HOW THE INDIVIDUAL TREE INFORMATION COULD
C         BE PUNCHED ON THE DATA CARDS AND THE APPROPRIATE FORMAT CARD
C         ASSOCIATED WITH THIS PARTICULAR DATA SET-UP.
C
C
C         COL
C         ---
C        1-3    IDENT --- TREE NUMBER, IF TREES HAVE NO NUMBER OR IDENTIFI-
C                         CATION, THE PROGRAM ASSIGNS A NUMBER IN THE ORDER
C                         THE DATA CARDS ARE READ.
C
C        4-5    ISP   ---  SPECIES CODE NUMBER
C
C                          01  WHITE ASH         07  SUGAR MAPLE
C                          02  BEECH             08  BLACK OAK
C                          03  BLACK CHERRY      09  CHESTNUT OAK
C                          04  ELM               10  RED OAK
C                          05  HICKORY           11  WHITE OAK
C                          06  RED MAPLE         12  YELLOW POPLAR
C
C
C        6-9    DBH   ---  TREE DIAMETER BREAST HEIGHT
C
C        10     IGRAD---  FOREST SERVICE STANDARD LOG GRADES FOR HARDWOOD
C                         FACTORY LUMBER,  BUTT LOG GRADES 1, 2, OR 3.
C
C        11-12 HT    ---  MERCHANTABLE HEIGHT IN FEET TO AN 8-INCH
C                         VARIABLE TOP DIAMETER INSIDE BARK.
C
C         IF THE ORDER OF THE VARIABLES READ IN IS THE SAME AS ABOVE AND
C         THE VARIABLES ARE LOCATED IN THE COLUMNS INDICATED, THEN THE
C         CORRECT FORMAT CARD (DATA CARD 1) IS:
C
C         (I3,I2,F4.1,I1,F2.0)
C
C         IF THE ORDER OF VARIABLES READ IS THE SAME AS ABOVE BUT THE DATA
C         ARE IN DIFFERENT COLUMNS, THEN YOU MUST CHANGE DATA CARD 1 TO
C         REFLECT THE CORRECT FORMAT.
C
C         IF THE NORMAL ORDER OF VARIABLES ABOVE IS NOT USED, THEN YOU MUST:
C         (1) CHANGE THE ORDER OF VARIABLES ON THE DATA READ STATEMENT LABELED
C         NO 50 IN THE PROGRAM, AND ALSO (2) SPECIFY THE CORRECT FORMAT ON
C         DATA CARD 1.
C           \
C
```

```
C
C     CARD NO 2  (TRANSFORMATION OF SPECIES CODES)
C
C        IF THE SPECIES CODES IN YOUR DATA DECK AGREE EXACTLY WITH OUR
C        SPECIES CODES INDICATED ABOVE, THEN DATA CARD 2 IS BLANK.
C
C        IF YOUR SPECIES CODES ARE DIFFERENT YOU MUST PUNCH A 1 IN COL 1
C        ON CARD 2, AND PUNCH THE TWO-DIGIT CODE YOU USE FOR WHITE ASH
C        IN COLS 5 AND 6, PUNCH YOUR CODE FOR BEECH IN COLS 7 AND 8, AND
C        CONTINUE FOR ALL TWELVE SPECIES.  CARD 2 IS PUNCHED FOLLOWING
C        FORMAT 501.  ANY SPECIES EXCEPT THOSE ABOVE WILL AUTOMATICALLY
C        BE ASSIGNED TO THE MISC GROUP AND LISTED SEPARATELY FROM THE
C        SAWTIMBER STAND.
C
C     CARD NO 3   (LBR PRICE CONTROL CARD)
C
C        IF YOU WISH TO USE THE LBR PRICES LISTED IN TABLE 2 OF THIS PAPER,
C        CARD 3 IS BLANK, OTHERWISE PUNCH A 1 IN COL 1 AND ENTER THE
C        NEW PRICE DATA ACCORDING TO FORMAT 505.  THE ORDER OF THE LBR
C        PRICES LISTED ON CARD 3 IS ASSOCIATED WITH THE ORDER OF SPECIES.
C
C
C     CARD NOS 4, 5, AND 6   (CONVERSION COST OPTION CARDS)
C
C        IF YOU WISH TO USE OUR STANDARD CONVERSION COSTS AT THE $70.00
C        LEVEL AS GIVEN IN TABLE 52, ALL THREE CARDS ARE BLANK.
C
C        IF YOU WISH TO CHANGE THE CONVERSION COST LEVEL, SAY, FROM
C        $70.00 TO $80.00, BUT MAINTAIN THE SAME GENERAL CURVE FORM IMPLICIT
C        IN TABLE 52, THEN PUNCH A 1 IN COL 1 DATA CARD 4 AND THE NEW
C        CONVERSION COST FOR THE 16-INCH DBH CLASS (80.00) IN COLS 5-10 DATA
C        CARD 4 (RIGHT-HAND ADJUSTED), AND LEAVE CARDS 5 AND 6 BLANK.
C
C        IF YOU WISH TO CHANGE THE CURVE FORM OR USE YOUR OWN SET OF
C        DIFFERENT CONVERSION COSTS, PUNCH A 2 IN COL 1 CARD 4, THEN THE
C        26 NEW CONVERSION COSTS STARTING WITH THE CONVERSION COST FOR
C        THE 11-INCH CLASS IN COLS 21-26 AND CONTINUING THROUGH THE 36-INCH
C        CLASS BY ONE-INCH CLASSES.  HENCE, YOU WILL BE PUNCHING THE
C        CONVERSION COSTS FOR THE 11- THRU 18-INCH DBH CLASSES ON CARD 4,
C        THE 19- THRU 30-INCH CLASSES ON CARD 5, AND THE 31- THRU 36-INCH
C        CLASSES ON CARD 6.  SEE FORMAT 510.
C
C
C     CARD NO 7   (OUTPUT CONTROL CARD)
C
C        THERE ARE 7 TYPES OF OUTPUT TABLES AVAILABLE.  IF YOU WISH ANY
C        OF THESE TABLES, PUNCH A 1 IN THE APPROPRIATE COLUMN AS SHOWN
C        BELOW.  IF YOU DO NOT WISH A PARTICULAR TABLE, LEAVE THE
C        APPROPRIATE COLUMN BLANK.
C
C        NOTE --   REGARDLESS OF THE CODE PUNCHED IN COL 7 THE USER WILL
C                  ALWAYS GET A STATEMENT INDICATING THE TOTAL NUMBER
C                  OF TREES AND THE NUMBER OF TREES EXCLUDED FROM THE
C                  SAWTIMBER LIST.  ALSO HE SHOULD ALWAYS GET A TABLE OF
C                  CONVERSION COSTS AND LBR PRICES USED IN THAT PARTICULAR
C                  COMPUTER RUN.  THE LATTER TWO TABLES ARE OMITTED IN THE
C                  FOLLOWING COMPUTER OUTPUT BECAUSE THEY ARE ILLUSTRATED IN
C                  TABLES 2 AND 52.
C
C
C
C                  COL                TYPE OF TABLE
```

```
C                   ---               -------------
C                   1                 NUMBER OF SAWTIMBER TREES
C                   2                 BOARD FOOT VOLUME OF SAWTIMBER
C                   3                 VALUE OF SAWTIMBER TREES
C                   4                 SUMMARY OF SAWTIMBER STAND BY SPECIES
C                                        AND GRADE
C                   5                 SUMMARY OF SAWTIMBER STAND BY DBH AND GRADE
C                   6                 LIST OF SAWTIMBER TREES SHOWING THE TREE
C                                        QUALITY INDEX, BOARD FOOT VOLUME, CUBIC
C                                        FEET, CORDS, AND TREE VALUE.
C                   7                 LIST OF TREES EXCLUDED FROM SAWTIMBER LIST
C                                        BECAUSE OF SIZE,  PECIES, LOG GRADE, OR
C                                        MERCH HT.
C
C
C     ************************************************************************
C
C        THIS COMPLETES THE LIST OF USER INSTRUCTIONS.  REMEMBER ALL
C        SEVEN OPTION CARDS MUST PRECEED THE DATA DECK
C
C   **************************************************************************
C
C
C
      DIMENSION ALPHA(36),BETA(36),GAMMA(36),CCOST(26),NUM(13,12,3),
     1VALUE(13,12,3),NOTOT(12),TOTVAL(12),DUMMY(12),USERCC(26),FMT(20),
     2NOXSP(12),VALXSP(12),ISMALL(500,3),SMALL(500,2),PRICE(12),
     3ISPCD(12)
      INTEGER VOLUME(13,12,3),TOTVOL(12),TOTBF,VOLXSP(12),OPT1,OPT2,OP3,
     1SP(99)
      REAL SPNAME*8(26),SPNAM*8(24)
C
C     LIST OF TREE SPECIES NAMES FOR WHICH WE HAVE DEVELOPED TREE VALUE
C     CONVERSION STANDARDS
C
      DATA SPNAME/'   WHITE',' ASH    ','     BEE','CH      ','  BLACK '
     1,'CHERRY  ','      EL','M       ','    HICK','ORY     ','   RED M'
     2,'APLE    ',' SUGAR  ','MAPLE   ','   BLACK',' OAK    ','  CHESTN'
     3,'UT OAK  ','    RED ','OAK     ','   WHITE',' OAK    ',' YELLOW '
     4,'POPLAR  ','      MI','SC      '/
      DATA SPNAM/'WHITE   ','ASH     ','        ','BEECH   ','BLACK   ',
     1'CHERRY  ','        ','ELM     ','        ','HICKORY ','RED     ',
     2'MAPLE   ','SUGAR   ','MAPLE   ','BLACK   ','OAK     ','CHESTNUT',
     3'OAK     ','RED     ','OAK     ','WHITE   ','OAK     ','YELLOW  ',
     4'POPLAR  '/
C
C
C     LIST OF STANDARD CONVERSION COSTS FROM TABLE 52 OF PAPER, USED IF
C     COL 1 CARD 4 IS BLANK OR ZERO.  LIST STARTS WITH 11-INCH DBH CLASS
C     AND CONTINUES THRU THE 36-INCH CLASS.   CONVERSION COSTS ARE IN
C     DOLLARS PER M BD FT.
C
C
      DATA CCOST/80.84,78.67,76.50,74.34,72.17,70.00,67.83,
     165.67,63.50,61.33,59.17,57.00,54.80,53.50,52.65,52.25,52.05,51.95,
     251.85,51.80,51.74,51.69,51.64,51.59,51.54,51.49/
C
C
C     LIST OF STANDARD HARDWOOD LBR PRICES FROM TABLE 2 OF PAPER.
C     THESE PRICES ARE USED IF DATA CARD 3 IS BLANK.  PRICES ARE FOR 4/4
C     INCH NO 1 COMMON LBR IN DOLLARS PER M.
C
```

```
C
      DATA PRICE/195.,142.,175.,145.,140.,190.,185.,155.,140.,155.,140.,
     1170./
C
C
C      LIST OF REGRESSION COEFFICIENTS USED TO SOLVE FOR THE APPROPRIATE
C      TREE QUALITY INDEX
C      WHERE:
C      TQI = ALPHA + BETA*DBH + GAMMA*HT
C      THE FIRST THREE NUMBERS IN EACH LIST APPLY TO LOG GRADES 1, 2, AND
C      3, RESPECTIVELY FOR THE SPECIES 1 WHICH IS WHITE ASH, AND THE
C      PATTERN IS REPEATED FOR ALL TWELVE SPECIES.
C
C
C
      DATA ALPHA/.52016,.42017,.19192,.63384,.56182,.43325,
     1.62909,.41975,.20834,.70931,.51667,.43276,.57123,.51371,.45999,
     2.54256,.70533,.46333,.59368,.43199,.36873,.79449,.52900,.55305,
     3.85192,.55315,.46905,.69524,.59992,.53211,.56518,.33601,.38063,
     4.51132,.63478,.41512/
      DATA BETA/.02554,.02779,.01458,.01341,.00840,.00825,
     1.02316,.02264,.02347,.01151,.01113,.00797,.01550,.00667,.00000,
     2.02047,.00202,.00008,.02170,.01369,.00952,.01372,.00994,.00354,
     3.00747,.00874,.00722,.01869,.01144,.00574,.02548,.02089,.01206,
     4.01549,.00880,.00946/
      DATA GAMMA/.00063,.00153,-.00666,.00383,.00267,.00169,
     1.00319,.00227,.00083,.00043,.00186,-.00003,.00476,.00224,.00000,
     2.00535,.00383,.00010,.00616,.00155,.00200,.00535,.00150,.00157,
     3.00406,.00181,.00061,.00418,.00242,.00189,.00464,.00177,.00065,
     4.00082,.00344,.00110/
C
C      LIST OF FORMATS FOR INPUT OF DATA
 500  FORMAT(20A4)
 501  FORMAT(I1,3X,12I2)
 505  FORMAT(I1,12F4.0)
 510  FORMAT(I1,3X,F6.2,10X,8F6.2/12F6.2/6F6.2)
 515  FORMAT(7I1)
C
C
C      LIST OF FORMATS FOR OUTPUT OF RESULTS AND TABLES
C
 600  FORMAT('1',40X,'SAMPLE LIST OF SAWTIMBER TREES LARGER THAN 11 INCH
     1ES DBH'//' ',3X,'TREE',8X,'SPECIES',8X,'DBH',3X,'CONVERSION',6X,
     2'PRICE',4X,'GRADE',3X,'MERCH',3X,'TREE QUALITY',2X,'CUBIC',3X,'COR
     3DS',3X,'BD FT',6X,'VALUE'/' ',3X,'NUMBER',27X,'COST PER M',4X,'#1
     4C LBR',12X,'HT',8X,'INDEX',6X,'FEET'/' ',52X,'PER M'/' ',130('-'))
 610  FORMAT('1', 2X,'OUT OF A TOTAL OF ',I5,' TREES, THERE WERE ',I5,'
     1TREES EXCLUDED FROM THE SAWTIMBER LIST BECAUSE OF'/' ',2X,'SMALL D
     2BH, NO STANDARD LOG GRADE, NO MERCHANTABLE HEIGHT, OR SPECIES CODE
     3 OUTSIDE OF ACCEPTABLE SPECIES LIST'//)
 611  FORMAT('0',14X,'TREES EXCLUDED FROM THE SAWTIMBER LIST:'
     1//'0',10X,'TREE NUMBER',10X,'SPECIES',10X,'DBH',10X,'GRADE',10X,'M
     2ERCH HEIGHT'//)
 615  FORMAT(' ',13X,I5,8X,2A8,5X,F4.1,12X,I1,20X,F3.0)
 620  FORMAT('1',20X,'TABLE OF CONVERSION COSTS AND PRICES OF NO 1 COMMO
     1N LBR USED IN THIS OUTPUT'//' ',20X,'CONVERSION COST PER M',45X,'P
     2RICE OF #1 COMMON PER M'/' ',13X,'DBH',4X,'COST',10X,'DBH',4X,'COS
     3T',37X,'SPECIES',13X,'PRICE'/' ',12X,'CLASS',16X,'CLASS'/' ',10X,4
     40('-'),26X,38('-')//)
 625  FORMAT(' ',4X,2(10X,I2,3X,F5.2),33X,2A8,8X,F6.2)
 630  FORMAT(' ',3X,I4,3X,2A8,3X,F4.1,3X,F7.2,8X,F7.2,5X,I1,5X,F4.0,6X,
     1F8.5,2X,F7.1,2X,F6.2,2X,F7.1,3X,F8.2)
```

```
  635 FORMAT('1',30X,'NUMBER OF SAWTIMBER TREES OF EACH SPECIES, GRADE,
     2AND DBH CLASS')
  640 FORMAT('0',130('*')/' ',2X,'SPECIES',2X,'GRADE',35X,'DIAMETER CLAS
     1S'/' ',21X,'12',7X,'14',7X,'16',7X,'18',7X,'20',7X,'22',7X,'24',7X
     2,'26',7X,'28',7X,'30',7X,'32+',6X,'TOTAL'/' ',130('*'))
  645 FORMAT('0',1X,A8,4X,'1',11(I9),I12)
  650 FORMAT(' ',1X,A8,4X,'2',11(I9),I12)
  655 FORMAT(' ',13X,'3',11(I9),I12)
  665 FORMAT('0',130('*')//' ',1X,'TOTAL',7X,'1',11(I9),I12/' ',13X,'2',
     111I9,I12/' ',13X,'3',11I9,I12//' ',130('*'))
  670 FORMAT('0',1X,'GRAND TOTAL',2X,11I9,I12)
  675 FORMAT('1',30X,'BOARD-FOOT VOLUME OF SAWTIMBER TREES BY SPECIES, G
     1RADE, AND DBH CLASS')
  680 FORMAT('0',1X,A8,4X,'1',2X,11I9,  I12/' ',  1X,A8,4X,'2',2X,11I9,
     1I12/' ',13X,'3',2X,11I9,I12)
  686 FORMAT('0',130('*')//' ',1X,'TOTAL',7X,'1',2X,11I9,I12/' ',13X,
     1'2',2X,11I9,I12/' ',13X,'3',2X,11I9,I12//' ',130('*'))
  687 FORMAT('0',1X,'GRAND TOTAL',4X,11I9,I12)
  688 FORMAT('1',30X,'VALUE OF SAWTIMBER TREES BY SPECIES, GRADE, AND DB
     1H CLASS')
  689 FORMAT('0',1X,A8,4X,'1',2X,11F9.2,F12.2/' ',1X,A8,4X,'2',2X,11F9.2
     1,F12.2/' ',13X,'3',2X,11F9.2,F12.2)
  691 FORMAT('0',130('*')//' ',1X,'TOTAL',7X,'1',2X,11F9.2,F12.2/' ',13X
     1,'2',2X,11F9.2,F12.2/' ',13X,'3',2X,11F9.2,F12.2//' ',130('*'))
  692 FORMAT('0',1X,'GRAND TOTAL',4X,11F9.2,F12.2)
  693 FORMAT('1',57X,'SPECIES SUMMARY'//' ',21X,'NUMBER OF TREES, VOLUME
     1, AND VALUE OF SAWTIMBER OF ALL DBH CLASSES, BY SPECIES AND GRADE'
     2)
  694 FORMAT('0',130('-')/' ',1X,'SPECIES',4X,'*',3X,'NUMBER OF SAWTIMBE
     1R TREES',10X,'*',9X,'BOARD FOOT VOLUME',12X,'*',9X,'VALUE OF SAWTI
     2MBER',11X,'*')
  695 FORMAT(' ',12X,'*',1X,3('GRADE      GRADE      GRADE    TOTAL   * ')
     1/' ',12X,'*',3X,2('1',9X,'2',9X,'3',14X,'*',3X),'1',9X,'2',9X,'3',
     214X,'*'/' ',130('-'))
  696 FORMAT('0',1X,A8/' ',1X,A8,2X,4(I6,4X),4(I6,4X),F6.2,3(4X,F6.2))
  697 FORMAT('0',130('*')/'0',2X,'TOTAL',4X,4(I6,4X),4(I6,4X),F6.2,    3(
     14X,F6.2))
  698 FORMAT('1',56X,'DIAMETER SUMMARY'//' ',22X,'NUMBER OF TREES, VOLUM
     1E, AND VALUE OF SAWTIMBER OF ALL SPECIES, BY DBH CLASS AND GRADE')
  699 FORMAT('0',130('-')/' ',1X,'DBH      ',4X,'*',3X,'NUMBER OF SAWTIMBE
     1R TREES',10X,'*',9X,'BOARD FOOT VOLUME',12X,'*',9X,'VALUE OF SAWTI
     2MBER',11X,'*')
  700 FORMAT('0',3X,I2,6X,4(I6,4X),4(I6,4X),  F6.2,3(4X,F6.2))
C
C
      READ(5,500) (FMT(I),I=1,20)
      READ(5,501) OP3,(ISPCD(J),J=1,12)
      IF(OP3.EQ.0) GO TO 6
      DO 7 J=1,99
    7 SP(J)=13
      DO 8 I=1,12
      K=ISPCD(I)
    8 SP(K)=I
    6 READ(5,505) OPT1,(DUMMY(J),J=1,12)
      IF(OPT1.EQ.0) GO TO 10
      DO 9 J=1,12
    9 PRICE(J)=DUMMY(J)
   10 READ(5,510) OPT2,COST,(USERCC(J),J=1,26)
      IF(OPT2.EQ.0) GO TO 25
      IF(OPT2.EQ.1) GO TO 20
      DO 15 J=1,26
   15 CCOST(J)=USERCC(J)
```

```
      GO TO 25
   20 DIFF=COST-70.00
      DO 18 J=1,26
   18 CCOST(J)=CCOST(J)+DIFF
   25 CONTINUE
      READ(5,515) ITAB1,ITAB2,ITAB3,ITAB4,ITAB5,ILIST,LSMT
      IF(ILIST.NE.0) WRITE(6,600)
      DO 30 J=1,12
      NOXSP(J)=0
      VOLXSP(J)=0
      VALXSP(J)=0.0
      NOTOT(J)=0
      TOTVOL(J)=0
      TOTVAL(J)=0.0
      DO 30 I=1,13
      DO 30 K=1,3
      NUM(I,J,K)=0
      VOLUME(I,J,K)=0
   30 VALUE(I,J,K)=0.0
      ICOUNT=0
      TOTBF=0
      SUMVAL=0.0
      JJ=0
      JK=0
      GO TO 50
   32 JK=JK+1
      ISMALL(JK,1)=IDENT
      ISMALL(JK,2)=ISP
      ISMALL(JK,3)=IGRAD
      SMALL(JK,1)=DBH
      SMALL(JK,2)=HT
      GO TO 50
   34 WRITE(6,610) JJ,JK
      IF(LSMT.EQ.0) GO TO 35
      WRITE(6,611)
      DO 36 I=1,JK
      K=ISMALL(I,2)
   36 WRITE(6,615) ISMALL(I,1), SPNAME(2*K-1),SPNAME(2*K),SMALL(I,1),
     1ISMALL(I,3), SMALL(I,2)
   35 WRITE(6,620)
      DO 37 I=1,12
      KK=I+10
      JK=KK+12
   37 WRITE(6,625) KK,CCOST(I),JK,CCOST(I+12),SPNAME(2*I-1),SPNAME(2*I),
     1PRICE(I)
      GO TO 58
   50 READ(5,FMT,END=34) IDENT,ISP,DBH,IGRAD,HT
      IF(OP3.EQ.0) GO TO 53
      K=SP(ISP)
      ISP=K
   53 JJ=JJ+1
      BFV=CORD*V3
      IF(IDENT.EQ.0) IDENT=JJ
      IF(HT.LT.1.0.OR.HT.GT.96.) GO TO 32
      IF(ISP.LT.1.OR.ISP.GT.12) GO TO 32
      V1=((DBH*DBH)*(DBH+190))/100000.
      V2=((HT*(168.-HT))/6400.)+(32./(100*HT))
      V3=475.+(3.*HT*HT)/128
      CORD=V1*V2
      CFV=92.*CORD
      IBFV=BFV+.5
      IDBH=DBH+.001
      DIA=IDBH
      N=IDBH-10
      IF(N.LT.1) GO TO 32
      FRAC=DBH-DIA
      DIFF=CCOST(N)-CCOST(N+1)
      CONV=CCOST(N)-FRAC*DIFF
      IF(IGRAD.LT.1.OR.IGRAD.GT.3) GO TO 32
      K=ISP*3-3+IGRAD
      TOI=BETA(K)*DBH-GAMMA(K)*HT+ALPHA(K)
      VAL=(TOI*PRICE(ISP)-CONV)*BFV/1000.
      IVAL=VAL*100+.5
      VAL=IVAL/100.
      J=(IDBH-9)/2
      IF(J.GT.11) J=11
      NUM(ISP,J,IGRAD)=NUM(ISP,J,IGRAD)+1
      NUM(13,J,IGRAD)=NUM(13,J,IGRAD)+1
      NUM(ISP,12,IGRAD)=NUM(ISP,12,IGRAD)+1
      NUM(13,12,IGRAD)=NUM(13,12,IGRAD)+1
      NOTOT(J)=NOTOT(J)+1
      ICOUNT=ICOUNT+1
      VOLUME(ISP,J,IGRAD)=VOLUME(ISP,J,IGRAD)+IBFV
      VOLUME(13,J,IGRAD)=VOLUME(13,J,IGRAD)+IBFV
      VOLUME(ISP,12,IGRAD)=VOLUME(ISP,12,IGRAD)+IBFV
      VOLUME(13,12,IGRAD)=VOLUME(13,12,IGRAD)+IBFV
      TOTVOL(J)=TOTVOL(J)+IBFV
      TOTBF=TOTBF+IBFV
      VALUE(ISP,J,IGRAD)=VALUE(ISP,J,IGRAD)+VAL
      VALUE(13,J,IGRAD)=VALUE(13,J,IGRAD)+VAL
      VALUE(ISP,12,IGRAD)=VALUE(ISP,12,IGRAD)+VAL
      VALUE(13,12,IGRAD)=VALUE(13,12,IGRAD)+VAL
      TOTVAL(J)=TOTVAL(J)+VAL
      SUMVAL=SUMVAL+VAL
      IF(ILIST.EQ.0) GO TO 50
      WRITE(6,630) IDENT,SPNAME(2*ISP-1),SPNAME(2*ISP),DBH,CONV,PRICE(IS
     1P),IGRAD,HT,TOI,CFV,CORD,BFV,VAL
      GO TO 50
   58 DO 56 I=1,12
      DO 56 J=1,3
      NOXSP(I)=NOXSP(I)+NUM(I,12,J)
      VOLXSP(I)=VOLXSP(I)+VOLUME(I,12,J)
   56 VALXSP(I)=VALXSP(I)+VALUE(I,12,J)
   60 IF(ITAB1.LT.1) GO TO 70
      WRITE(6,635)
      WRITE(6,640)
      DO 55 I=1,12
      IF(NOXSP(I).EQ.0) GO TO 55
      WRITE(6,645) SPNAM(2*I-1),(NUM(I,J,1),J=1,12)
      WRITE(6,650) SPNAM(2*I),(NUM(I,J,2),J=1,12)
      WRITE(6,655) (NUM(I,J,3),J=1,12)
   55 CONTINUE
      WRITE(6,665) (NUM(13,J,1),J=1,12),(NUM(13,K,2),K=1,12),(NUM(13,L,3
     1),L=1,12)
      WRITE(6,670) (NOTOT(J),J=1,11),ICOUNT
   70 IF(ITAB2.LT.1) GO TO 80
      WRITE(6,675)
      WRITE(6,640)
      DO 65 I=1,12
      IF(NOXSP(I).EQ.0) GO TO 65
      WRITE(6,680) SPNAM(2*I-1),(VOLUME(I,J,1),J=1,12),SPNAM(2*I),(VOLUM
     1E(I,K,2),K=1,12),(VOLUME(I,L,3),L=1,12)
   65 CONTINUE
      WRITE(6,686) (VOLUME(13,J,1),J=1,12),(VOLUME(13,K,2),K=1,12),(VOLU
  1ME(13,L,3),L=1,12)
   WRITE(6,687)(TOTVOL(J),J=1,11),TOTBF
80 IF(ITAB3.LT.1) GO TO 90
   WRITE(6,688)
   WRITE(6,640)
   DO 75 I=1,12
   IF(NOXSP(I).EQ.0) GO TO 75
   WRITE(6,689) SPNAM(2*I-1),(VALUE(I,J,1),J=1,12),SPNAM(2*I),(VALUE(
  1I,K,2),K=1,12),(VALUE(I,L,3),L=1,12)
75 CONTINUE
   WRITE(6,691) (VALUE(13,J,1),J=1,12),(VALUE(13,K,2),K=1,12),(VALUE(
  113,L,3),L=1,12)
   WRITE(6,692) (TOTVAL(J),J=1,11),SUMVAL
90 IF(ITAB4.LT.1) GO TO 96
   WRITE(6,693)
   WRITE(6,694)
   WRITE(6,695)
   DO 94 I=1,12
   IF(NOXSP(I).EQ.0) GO TO 94
   WRITE(6,696)SPNAM(2*I-1),SPNAM(2*I),(NUM(I,12,K),K=1,3),NOXSP(I),
  1(VOLUME(I,12,J),J=1,3),VOLXSP(I),(VALUE(I,12,L),L=1,3),VALXSP(I)
94 CONTINUE
   WRITE(6,697) (NUM(13,12,J),J=1,3),ICOUNT,(VOLUME(13,12,K),K=1,3),
  1TOTBF,(VALUE(13,12,L),L=1,3),SUMVAL
96 IF(ITAB5.LT.1) GO TO 99
   WRITE(6,698)
   WRITE(6,699)
   WRITE(6,695)
   DO 98 J=1,12
   IF(J.LT.12) GO TO 97
   WRITE(6,697) (NUM(13,J,K),K=1,3),ICOUNT,(VOLUME(13,J,L),L=1,3),TOT
  1BF,(VALUE(13,J,M),M=1,3),SUMVAL
   GO TO 98
97 JJ=J*2+10
   WRITE(6,700) JJ,(NUM(13,J,K),K=1,3),NOTOT(J),(VOLUME(13,J,L),L=1,3
  1),TOTVOL(J),(VALUE(13,J,M),M=1,3),TOTVAL(J)
98 CONTINUE
99 STOP
   END
```

Figure 2

SAMPLE LIST OF SAWTIMBER TREES LARGER THAN 11 INCHES DBH

TREE NUMBER	SPECIES	DBH	CONVERSION COST PER M	PRICE #1 C LBR PER M	GRADE	MERCH HT	TREE QUALITY INDEX	CUBIC FEET	CORDS	BD FT	VALUE
7	WHITE OAK	11.7	79.32	140.00	3	16.	0.51133	10.2	0.11	53.1	-0.40
8	WHITE OAK	12.6	77.37	140.00	3	40.	0.50659	23.9	0.26	133.2	-0.85
10	CHESTNUT OAK	12.3	78.02	140.00	3	24.	0.54322	15.6	0.17	82.7	-0.15
11	BLACK OAK	14.7	72.82	155.00	2	32.	0.62712	28.1	0.31	152.3	3.71
12	BLACK OAK	17.3	67.18	155.00	2	40.	0.64096	46.1	0.50	256.9	8.26
13	BLACK OAK	13.2	76.07	155.00	3	32.	0.54954	22.5	0.24	121.9	1.11
14	WHITE OAK	11.1	80.62	140.00	3	24.	0.49890	12.6	0.14	67.0	-0.71
15	WHITE OAK	13.4	75.64	140.00	3	32.	0.52143	23.2	0.25	125.8	-0.32
17	WHITE OAK	15.3	71.52	140.00	2	32.	0.59899	30.5	0.33	165.5	2.04
18	WHITE OAK	13.0	76.50	140.00	3	32.	0.51661	21.8	0.24	118.1	-0.48
21	WHITE OAK	14.7	72.82	140.00	3	32.	0.53711	28.1	0.31	152.3	0.36
22	WHITE OAK	15.0	72.17	140.00	2	40.	0.57856	34.3	0.37	191.0	1.69
23	RED OAK	18.2	65.24	155.00	2	40.	0.71133	51.3	0.56	285.6	12.86
24	WHITE OAK	14.4	73.47	140.00	2	40.	0.56603	31.5	0.34	175.5	1.01
25	WHITE OAK	13.4	75.64	140.00	3	24.	0.52663	18.6	0.20	98.7	-0.18
26	CHESTNUT OAK	12.6	77.37	140.00	3	24.	0.54538	16.4	0.18	86.9	-0.08
27	CHESTNUT OAK	14.6	73.04	140.00	3	24.	0.55982	22.2	0.24	117.9	0.63
28	BLACK OAK	18.0	65.67	155.00	1	48.	0.78465	56.2	0.61	323.2	18.08
31	CHESTNUT OAK	16.1	69.78	140.00	2	40.	0.62146	39.7	0.43	221.2	3.81
32	CHESTNUT OAK	13.9	74.56	140.00	2	32.	0.61672	25.0	0.27	135.6	1.60
33	BLACK OAK	16.7	68.48	155.00	1	40.	0.80961	42.9	0.47	238.7	13.61
34	CHESTNUT OAK	15.0	72.17	140.00	2	24.	0.64081	23.5	0.26	124.7	2.19
36	CHESTNUT OAK	12.4	77.80	140.00	3	16.	0.54882	11.5	0.12	59.9	-0.05
37	CHESTNUT OAK	16.0	70.00	140.00	2	32.	0.63507	33.5	0.36	181.6	3.43
42	CHESTNUT OAK	12.1	78.45	140.00	3	16.	0.54665	10.9	0.12	56.9	-0.10
43	CHESTNUT OAK	12.8	76.93	140.00	3	16.	0.55171	12.2	0.13	63.9	0.02
44	RED OAK	25.1	52.61	155.00	1	40.	0.99716	100.7	1.09	561.2	57.21
45	CHESTNUT OAK	13.1	76.28	140.00	3	24.	0.54899	17.7	0.19	94.2	0.05
49	WHITE OAK	12.0	78.67	140.00	3	24.	0.50975	14.8	0.16	78.6	-0.56
50	WHITE OAK	18.3	65.02	140.00	2	40.	0.64750	51.9	0.56	288.9	7.40
51	WHITE OAK	15.6	70.87	140.00	2	40.	0.59109	37.2	0.40	207.2	2.46
54	WHITE OAK	17.6	66.53	140.00	1	56.	0.75379	58.3	0.63	347.7	13.56
55	WHITE OAK	11.2	80.41	140.00	3	16.	0.50530	9.3	0.10	48.6	-0.46
57	BLACK OAK	20.2	60.90	155.00	1	48.	0.81483	71.5	0.78	411.4	26.90
58	RED OAK	19.6	62.20	155.00	1	48.	0.86092	67.2	0.73	386.2	27.51
59	WHITE OAK	17.4	66.97	140.00	1	48.	0.78581	52.4	0.57	301.2	12.96
60	BLACK OAK	11.9	78.89	155.00	3	24.	0.55750	14.6	0.16	77.3	0.58
61	CHESTNUT OAK	12.7	77.15	140.00	3	24.	0.54610	16.6	0.18	88.4	-0.05
62	WHITE OAK	18.8	63.93	140.00	1	40.	0.85860	54.9	0.60	305.6	17.20
63	WHITE OAK	13.9	74.56	140.00	2	40.	0.55558	29.3	0.32	163.1	0.53
64	BLACK OAK	17.9	65.89	155.00	2	24.	0.67093	33.9	0.37	180.1	6.86
67	WHITE OAK	11.0	80.84	140.00	3	24.	0.49769	12.4	0.13	65.7	-0.72
69	WHITE OAK	14.0	74.34	140.00	2	32.	0.57183	25.4	0.28	137.7	0.79
70	BLACK OAK	22.7	55.46	155.00	1	40.	0.89193	81.5	0.89	453.9	37.58
71	WHITE OAK	21.2	58.74	140.00	1	56.	0.84552	86.1	0.94	513.2	30.61
72	WHITE OAK	13.2	76.07	140.00	3	24.	0.52422	18.0	0.20	95.7	-0.25
74	WHITE OAK	13.6	75.20	140.00	3	32.	0.52385	23.9	0.26	129.7	-0.23
75	WHITE OAK	12.8	76.93	140.00	3	32.	0.51420	21.1	0.23	114.4	-0.56
76	BLACK OAK	17.1	67.61	155.00	1	40.	0.81510	45.0	0.49	250.8	14.73
78	WHITE OAK	13.7	74.99	140.00	3	32.	0.52505	24.3	0.26	131.6	-0.18
79	CHESTNUT OAK	17.9	65.89	140.00	1	24.	0.88819	33.9	0.37	180.1	10.53
80	RED OAK	25.0	52.65	155.00	1	32.	1.02873	85.3	0.93	462.7	49.41
81	BLACK OAK	19.7	61.98	155.00	1	48.	0.80797	67.9	0.74	390.3	24.69
82	BLACK OAK	13.7	74.99	155.00	3	24.	0.56387	19.5	0.21	103.3	1.28
83	WHITE OAK	17.0	67.83	140.00	2	48.	0.60618	49.9	0.54	286.9	4.89
87	BLACK OAK	19.7	61.98	155.00	1	32.	0.89357	51.7	0.56	280.2	21.44

Figure 3

```
OUT OF A TOTAL OF    89 TREES, THERE WERE    32 TREES EXCLUDED FROM THE SAWTIMBER LIST BECAUSE OF
SMALL DBH, NO STANDARD LOG GRADE, NO MERCHANTABLE HEIGHT, OR SPECIES CODE OUTSIDE OF ACCEPTABLE SPECIES LIST


      TREES EXCLUDED FROM THE SAWTIMBER LIST:


    TREE NUMBER        SPECIES          DBH        GRADE        MERCH HEIGHT


           1           RED OAK          14.7         0               24.
           2           RED OAK          19.3         0               48.
           3        CHESTNUT OAK         7.6         0                0.
           4        CHESTNUT OAK        12.1         0               24.
           5          WHITE OAK          7.1         0                0.
           6           RED OAK          17.9         0               40.
           9          WHITE OAK          9.2         0                0.
          16           HICKORY           6.6         0                0.
          19          WHITE OAK          9.6         0                0.
          20          WHITE OAK          9.4         0                0.
          29        CHESTNUT OAK        12.0         0               24.
          30        CHESTNUT OAK         9.4         0                0.
          35          WHITE OAK          8.7         0                0.
          38          RED MAPLE          6.6         0                0.
          39          WHITE OAK         10.4         0                0.
          40          RED MAPLE          5.4         0                0.
          41        CHESTNUT OAK         9.1         0                0.
          46           HICKORY           5.7         0                0.
          47          WHITE ASH         10.9         0                0.
          48        CHESTNUT OAK         8.0         0                0.
          52          WHITE OAK          9.8         0                0.
          53          WHITE OAK          9.2         0                0.
          56        YELLOW POPLAR        7.6         0                0.
          65          WHITE OAK         10.9         0                0.
          66          WHITE OAK         16.5         0               24.
          68          WHITE OAK          7.4         0                0.
          73          WHITE OAK         10.7         0                0.
          77          WHITE OAK          7.6         0                0.
          84        CHESTNUT OAK        10.9         0                0.
          85          WHITE OAK          8.9         0                0.
          86          WHITE OAK          8.3         0                0.
          88        YELLOW POPLAR        7.6         0                0.
```

Figure 4

NUMBER OF SAWTIMBER TREES OF EACH SPECIES, GRADE, AND DBH CLASS

SPECIES	GRADE	DIAMETER CLASS 12	14	16	18	20	22	24	26	28	30	32+	TOTAL
BLACK	1	0	0	1	2	3	1	0	0	0	0	0	7
OAK	2	0	1	0	2	0	0	0	0	0	0	0	3
	3	1	2	0	0	0	0	0	0	0	0	0	3
CHESTNUT	1	0	0	0	1	0	0	0	0	0	0	0	1
OAK	2	0	1	3	0	0	0	0	0	0	0	0	4
	3	6	2	0	0	0	0	0	0	0	0	0	8
RED	1	0	0	0	0	1	0	0	2	0	0	0	3
OAK	2	0	0	0	1	0	0	0	0	0	0	0	1
	3	0	0	0	0	0	0	0	0	0	0	0	0
WHITE	1	0	0	0	3	0	1	0	0	0	0	0	4
OAK	2	0	3	4	2	0	0	0	0	0	0	0	9
	3	7	7	0	0	0	0	0	0	0	0	0	14
TOTAL	1	0	0	1	6	4	2	0	2	0	0	0	15
	2	0	5	7	5	0	0	0	0	0	0	0	17
	3	14	11	0	0	0	0	0	0	0	0	0	25
GRAND TOTAL		14	16	8	11	4	2	0	2	0	0	0	57

Figure 5

```
                    BOARD-FOOT VOLUME OF SAWTIMBER TREES BY SPECIES, GRADE, AND DBH CLASS

*******************************************************************************************************
 SPECIES  GRADE                                  DIAMETER CLASS
                 12       14       16       18       20       22       24       26       28       30      32+     TOTAL
*******************************************************************************************************

BLACK      1      0        0      239      574     1081      454        0        0        0        0        0      2348
OAK        2      0      152        0      437        0        0        0        0        0        0        0       589
           3     77      225        0        0        0        0        0        0        0        0        0       302

CHESTNUT   1      0        0        0      180        0        0        0        0        0        0        0       180
OAK        2      0      136      528        0        0        0        0        0        0        0        0       664
           3    439      212        0        0        0        0        0        0        0        0        0       651

RED        1      0        0        0        0      386        0        0     1024        0        0        0      1410
OAK        2      0        0        0      286        0        0        0        0        0        0        0       286
           3      0        0        0        0        0        0        0        0        0        0        0         0

WHITE      1      0        0        0      955        0      513        0        0        0        0        0      1468
OAK        2      0      477      759      576        0        0        0        0        0        0        0      1812
           3    561      853        0        0        0        0        0        0        0        0        0      1414

*******************************************************************************************************

TOTAL      1      0        0      239     1709     1467      967        0     1024        0        0        0      5406
           2      0      765     1287     1299        0        0        0        0        0        0        0      3351
           3   1077     1290        0        0        0        0        0        0        0        0        0      2367

*******************************************************************************************************

GRAND TOTAL    1077     2055     1526     3008     1467      967        0     1024        0        0        0     11124
```

Figure 6

```
                           VALUE OF SAWTIMBER TREES BY SPECIES, GRADE, AND DBH CLASS

*******************************************************************************************************
 SPECIES  GRADE                                     DIAMETER CLASS
                 12       14       16       18       20       22       24       26       28       30       32+      TOTAL
*******************************************************************************************************

BLACK       1     0.0      0.0     13.61    32.81    73.03    37.58     0.0      0.0      0.0      0.0      0.0     157.03
OAK         2     0.0      3.71     0.0     15.12     0.0      0.0      0.0      0.0      0.0      0.0      0.0      18.83
            3     0.58     2.39     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0       2.97

CHESTNUT    1     0.0      0.0      0.0     10.53     0.0      0.0      0.0      0.0      0.0      0.0      0.0      10.53
OAK         2     0.0      1.60     9.43     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      11.03
            3    -0.41     0.68     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0       0.27

RED         1     0.0      0.0      0.0      0.0     27.51     0.0      0.0    106.62     0.0      0.0      0.0     134.13
OAK         2     0.0      0.0      0.0     12.86     0.0      0.0      0.0      0.0      0.0      0.0      0.0      12.86
            3     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0       0.0

WHITE       1     0.0      0.0      0.0     43.72     0.0     30.61     0.0      0.0      0.0      0.0      0.0      74.33
OAK         2     0.0      2.33     9.91    12.29     0.0      0.0      0.0      0.0      0.0      0.0      0.0      24.53
            3    -4.26    -1.28     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      -5.54

*******************************************************************************************************

TOTAL       1     0.0      0.0     13.61    87.06   100.54    68.19     0.0    106.62     0.0      0.0      0.0     376.02
            2     0.0      7.64    19.34    40.27     0.0      0.0      0.0      0.0      0.0      0.0      0.0      67.25
            3    -4.09     1.79     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      -2.30

*******************************************************************************************************

GRAND TOTAL      -4.09     9.43    32.95   127.33   100.54    68.19     0.0    106.62     0.0      0.0      0.0     440.97
```

Figure 7

```
                                        SPECIES SUMMARY

          NUMBER OF TREES, VOLUME, AND VALUE OF SAWTIMBER OF ALL DBH CLASSES, BY SPECIES AND GRADE

------------------------------------------------------------------------------------------------------------------
SPECIES   *  NUMBER OF SAWTIMBER TREES           *      BOARD FOOT VOLUME             *     VALUE OF SAWTIMBER           *
          * GRADE    GRADE    GRADE    TOTAL     * GRADE    GRADE    GRADE    TOTAL   * GRADE    GRADE    GRADE    TOTAL  *
          *   1        2        3                *   1        2        3              *   1        2        3             *
------------------------------------------------------------------------------------------------------------------

BLACK
OAK           7        3        3        13       2348      589      302     3239    157.03    18.83     2.97   178.83

CHESTNUT
OAK           1        4        8        13        180      664      651     1495     10.53    11.03     0.27    21.83

RED
OAK           3        1        0         4       1410      286        0     1696    134.13    12.86     0.0    146.99

WHITE
OAK           4        9       14        27       1468     1812     1414     4694     74.33    24.53    -5.54    93.32

******************************************************************************************************************

 TOTAL       15       17       25        57       5406     3351     2367    11124    376.02    67.25    -2.30   440.97
```

Figure 8

```
                                          DIAMETER SUMMARY

           NUMBER OF TREES, VOLUME, AND VALUE OF SAWTIMBER OF ALL SPECIES, BY DBH CLASS AND GRADE

----------------------------------------------------------------------------------------------------------
DBH      *   NUMBER OF SAWTIMBER TREES        *      BOARD FOOT VOLUME          *      VALUE OF SAWTIMBER          *
         * GRADE   GRADE   GRADE   TOTAL      * GRADE   GRADE   GRADE   TOTAL   * GRADE    GRADE   GRADE   TOTAL   *
         *   1       2       3                *   1       2       3             *   1        2       3             *
----------------------------------------------------------------------------------------------------------

 12          0       0      14      14          0       0    1077    1077      0.0      0.0     -4.09    -4.09

 14          0       5      11      16          0     765    1290    2055      0.0      7.64     1.79     9.43

 16          1       7       0       8        239    1287       0    1526     13.61    19.34     0.0     32.95

 18          6       5       0      11       1709    1299       0    3008     87.06    40.27     0.0    127.33

 20          4       0       0       4       1467       0       0    1467    100.54     0.0      0.0    100.54

 22          2       0       0       2        967       0       0     967     68.19     0.0      0.0     68.19

 24          0       0       0       0          0       0       0       0      0.0      0.0      0.0      0.0

 26          2       0       0       2       1024       0       0    1024    106.62     0.0      0.0    106.62

 28          0       0       0       0          0       0       0       0      0.0      0.0      0.0      0.0

 30          0       0       0       0          0       0       0       0      0.0      0.0      0.0      0.0

 32          0       0       0       0          0       0       0       0      0.0      0.0      0.0      0.0

**********************************************************************************************************

 TOTAL      15      17      25      57       5406    3351    2367   11124    376.02    67.25    -2.30   440.97
```

Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
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- Pennington, New Jersey.
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- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- Warren, Pennsylvania.

Mendel, J. J., P. S. DeBald and M. E. Dale.
1976. **Tree value conversion standards for hardwood sawtimber.** (SETs: Stand Evaluation Tools. 2) Northeast For. Exp. Stn., Upper Darby, Pa.
74 p., illus. (USDA For. Serv. Res. Pap. NE-337)

Tree quality index tables are presented for 12 important hardwood species of the oak-hickory forest. From these, tree value conversion standards are developed for each species, log grade, merchantable height, and diameter at breast height. The method of calculating tree value conversion standards and adapting them to different conditions is explained. A computer program for calculating tree values for different timber values and conversion costs is included.

653 + 652 + 176.1

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III. Composite Volume and Value Tables for Hardwood Pulpwood

MAR 24

by Paul S. DeBald
and Joseph J. Mendel

USDA FOREST SERVICE RESEARCH PAPER NE-338
1976

FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

SETs

THIS IS ONE of a series of papers designed to help the forester estimate the value of timber stands. We call these papers SETs — Stand Evaluation Tools. The first three papers are being published concurrently. They are:

SETs I. AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS (USDA Forest Service Research Paper NE-336), which describes a method for using individual tree values to make stand evaluations.

SETs II. TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER (USDA Forest Service Research Paper NE-337), which provides values for individual sawtimber trees.

SETs III. COMPOSITE VOLUME AND VALUE TABLES FOR HARDWOOD PULPWOOD (USDA Forest Service Research Paper NE-338), which provides values for individual growing-stock trees.

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MANUSCRIPT RECEIVED FOR PUBLICATION 20 FEBRUARY 1975

SETs: Stand Evaluation Tools.

III. Composite Volume and Value Tables for Hardwood Pulpwood

ABSTRACT

This paper presents 38 composite volume and value tables for hardwood pulpwood. Values are given for multiples of commonly used bolt lengths – 4, 5, and 8 feet – and may be applied, generally, to standing trees of all hardwood species. The volume tables resemble closely the Lake States Composite Volume Tables, but extend them to other units of measure: cubic feet, tons, cubic meters, and metric tons. The value tables give dollar values for individual trees at a wide range of pulpwood prices. Both sets of tables may be used with either entire trees or the pulpwood portions of sawtimber trees. Examples of such applications are provided.

INTRODUCTION

THIS PAPER has three purposes:

(1) to expand the usefulness of the Lake States Composite Volume Tables (*Gevorkiantz and Olsen 1955*).

(2) to provide a set of tree-value tables for pulpwood.

(3) to serve as a companion paper to TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER, and AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS, which are being published concurrently.

As Volume Tables

The Lake States Composite Volume Tables are widely used in the eastern United States because, being composite tables, they can be applied to the average run of timber, regardless of species (*Beers 1964, Myers 1972*). This is important in diverse eastern forests. But the Lake States Tables, as originally published, have a drawback: they may require considerable interpolation (*Ek 1971*).

Efforts have been made to overcome this drawback. Beers and Ek offer volume equations for expanding several of the Lake States Tables with either a desk calculator or a computer. The Forest Service has published look-up volume tables based on the Lake States Tables: Region 9 CFI Newsletters 129 and 131 (*USDA Forest Service 1964, 1965*).

In this paper we further extend the Lake States Composite Volume Tables by interpolating values for 4- and 5-foot bolt lengths and converting them into various measures of volume and weight: cords, cubic feet, cubic meters, tons, and metric tons. We made the metric conversions to provide a crosswalk between English and metric units within the Lake States Tables.

Value Tables

A hardwood tree's value as pulpwood usually depends on its volume, seldom on its species, so the Lake States Composite Volume Tables provide an excellent base for converting tree volumes to standing tree values. All that is needed is to multiply the composite tree volumes by appropriate stumpage values. But this is a tedious and costly operation, one that could discourage a potential user. We elected to lighten the user's job by making a number of such conversions for him, using our extended volume tables and a wide range of stumpage values per cord. The resulting composite value tables give individual tree values for pulpwood on the stump at various stumpage prices. These value tables can be applied, generally, to all hardwood species.

Companion Tables

In recent years, Forest Service scientists have published a series of papers dealing with the rates of value increase for most of the important hardwood species. In the course of deriving rates of value increase, tree value conversion standards had to be calculated. That work has been summarized in TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER which is being published concurrently with this paper and which presents tree value conversion standards for 12 species by butt log grade, dbh, and merchantable height (*Mendel, DeBald, and Dale 1976*). The standards can be used in estimating the values and in evaluating the development of either individual sawtimber trees or the sawtimber portions of forest stands. The pulpwood tree values that we present here can be combined with those sawtimber standards to estimate the timber value of entire forest stands and to evaluate their development over time. This is discussed in a third paper—AN INDIVIDUAL-TREE APPROACH TO MAKING STAND EVALUATIONS — which is also being published concurrently (*DeBald and Mendel 1976*).

Method

The composite volume tables in appendix A were generated with the following equation:

$$\text{volume in cords} = \frac{D^2(D+190)\left[\dfrac{H(168-H)}{64} + \dfrac{32}{H}\right]}{10^7}$$

where: D = dbh (in inches) and
H = merchantable height (in feet) to a variable 4-inch top.

This equation is an adaptation of the one that Beers derived to approximate Lake States Composite Volume Table Number 6.

Cord volumes were converted to other units of measure by multiplying them by the following factors:

(a) 79, for cubic feet
(b) 2.25, for tons of soft hardwoods
(c) 2.50, for tons of hard hardwoods
(d) 2.212, for cubic meters
(e) 2.04, for metric tons of soft hardwoods
(f) 2.27, for metric tons of hard hardwoods

Soft hardwoods include such species as basswood, yellow-poplar, aspen, cottonwood, willow, and soft maple. Hard hardwoods include such species as oak, hickory, hard maple, and beech.

The composite value tables (appendix B) were computed by applying dollar values to the cord volumes.

APPLICATIONS

The composite volume tables given here may be read directly. They may also be used to estimate the pulpwood volumes in the upper stems of small sawtimber trees, although applying these composite tables to merchantable heights that are measured above forks or large branches will lead to overestimation of volumes.

Take, for example, a 14-inch tree whose sawlog portion contains two 16-foot logs and whose upper stem contains one 8-foot pulp bolt. If it were used strictly for pulpwood, that tree's gross volume would be .323 cords — the volume of a 14-inch tree with a 40-foot merchantable height (table 1). The volume of the sawlog portion is .276 cords — the volume of a 14-inch tree with a 32-foot merchantable height. The volume of the upper stem would thus be .047 cords — the difference between .323 cords and .276 cords.

The composite value tables make it possible to look up pulpwood values for individual trees, which may be either gross values on the stump (stumpage values) or net values at any processing stage from stump to millyard (conversion values).

Finding a tree's stumpage value is easy. Just look up the tree's dbh and merchantable height in the appropriate pulpwood value table. Tables for a wide range of stumpage prices, from $1 to $25 per cord, are provided in appendix B.

Finding a tree's conversion value takes an additional step. First, take the value of pulpwood at some point in its processing (a price at roadside may be convenient); say, for example, $12 per cord. From that subtract the estimated costs of processing the pulpwood to that point — felling, bucking, limbing, and skidding. Here, say the cost is $10 per cord. The difference, in this case $2, between the pulpwood price at roadside and the costs of getting the pulpwood there may be used as a base for estimating individual tree values. So, in this example, we would estimate conversion values for individual trees by using table 19 for a stumpage value of $2 per cord.

To estimate the value of pulpwood bolts in the upper stems of sawtimber trees, we would use an approach similar to the one we used to estimate the pulpwood volume in the upper stem of a 14-inch tree. So, let's look again at that same tree: a 14-inch tree that contains two 16-foot sawlogs, topped with one 8-foot pulp bolt. If pulpwood stumpage were $2.50 per cord, the tree's upper stem would be worth $0.12 (table 21). This is the difference in value between a 14-inch tree that has 40 feet of merchantable height ($0.81) and one that has 32 feet of merchantable height ($0.69).

As noted earlier, the composite pulpwood values can be used in conjunction with sawtimber conversion standards to estimate the timber values of entire forest stands and evaluate their development. When used together, the pulpwood and sawtimber values cover the entire range of merchantable diameters in a stand and reflect timber values in terms of the two most common timber products.

Many small sawtimber trees lack quality— just because of their small diameters — and will yield little value as 4/4 lumber. For some, even, conversion costs would exceed their lumber value. Many of these trees have more value as pulpwood, so it is important to be able to assign pulpwood values to small sawtimber trees, if for no other reason than to avoid working with negative tree value conversion standards.

To integrate pulpwood values with sawtimber value standards, we can simply compare the appropriate value tables and assign individual trees the higher of the two product values. The crossover point between pulpwood value and sawtimber value will vary with species, pulpwood and lumber prices, conversion costs, tree size, and tree quality.

We can also add a refinement by combining products in a single tree. Let's take the 14-inch sample tree that we have been using and, this time, say that it is a red oak with a Grade 2 butt log. We can combine pulpwood and lumber values for this tree as follows:

		Pulpwood[a] only	Lumber[b] only	Pulpwood and lumber combined
Sawlog portion	(32′)	$0.69	$4.40	$4.40
Upper stem	(8′)	.12	—	.12
Total	(40′)	.81	4.40	4.52

[a] Table 21.

[b] From TREE VALUE CONVERSION STANDARDS FOR HARDWOOD SAWTIMBER.

This procedure can be used in hand computations, such as cut and leave tallies, by looking up the values directly. It can also be incorporated into computerized inventory systems in much the same way as volume tables are. Either way, it can be applied both to individual tree tallies and to stand tables. The resulting values can then be totaled to obtain stand summaries.

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APPENDIX A

Pulpwood Volumes

Table				
1, 2	Gross	volume	in	cords
3, 4	"	"	"	cubic feet
5, 6	"	"	"	cubic meters
7, 8	"	weight	"	tons for soft hardwoods
9, 10	"	"	"	tons for hard hardwoods
11, 12	"	"	"	metric tons for soft hardwoods
13, 14	"	"	"	metric tons for hard hardwoods

All volumes are to top diameters that are variable, but not less than 4.0 inches.

Odd-numbered tables are for 4-foot merchantable lengths.

Even-numbered tables are for 5-foot merchantable lengths.

Table 1. — Gross volume in cords

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.012	0.016	0.019	0.023	0.027	—	—	—	—	—	—	—	—	—	—
6	.017	.023	.028	.034	.039	0.044	0.049	—	—	—	—	—	—	—	—
7	.023	.031	.039	.046	.053	.060	.067	0.073	0.078	—	—	—	—	—	—
8	.030	.040	.051	.061	.070	.079	.087	.095	.102	0.109	0.115	—	—	—	—
9	.039	.051	.064	.077	.089	.101	.111	.121	.130	.139	.146	0.153	0.159	—	—
10	.048	.064	.080	.096	.111	.125	.138	.150	.162	.172	.181	.190	.197	—	—
11	.058	.078	.097	.116	.135	.152	.168	.183	.197	.209	.221	.231	.240	0.248	0.254
12	.070	.093	.116	.139	.161	.181	.201	.219	.235	.250	.264	.276	.287	.296	.304
13	.082	.109	.137	.164	.190	.214	.237	.258	.277	.295	.311	.325	.338	.349	.359
14	.096	.128	.160	.191	.221	.249	.276	.300	.323	.344	.363	.379	.394	.407	.418
15	.111	.147	.184	.221	.255	.288	.318	.347	.373	.397	.418	.438	.455	.469	.482
16	.127	.168	.211	.252	.292	.329	.364	.396	.426	.453	.478	.500	.520	.537	.551
17	.144	.191	.239	.286	.331	.373	.413	.450	.483	.514	.542	.568	.590	.609	.625
18	.162	.215	.270	.322	.373	.420	.465	.506	.545	.579	.611	.639	.664	.686	.704
19	.181	.241	.302	.361	.417	.471	.521	.567	.610	.649	.684	.716	.744	.768	.788
20	.202	.268	.336	.402	.465	.524	.580	.631	.679	.722	.762	.797	.828	.855	.878
21	.223	.297	.372	.445	.515	.581	.642	.699	.752	.800	.844	.883	.917	.947	.972
22	.246	.327	.410	.491	.568	.640	.708	.771	.829	.882	.930	.973	1.011	1.044	1.072
23	.270	.360	.451	.539	.623	.703	.777	.847	.910	.969	1.022	1.069	1.111	1.147	1.177
24	.296	.393	.493	.590	.682	.769	.851	.926	.996	1.060	1.118	1.169	1.215	1.255	1.288

Table 2. — Gross volume in cords

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.014	0.019	0.023	—	—	—	—	—	—	—	—	—
6	.020	.027	.034	0.040	—	—	—	—	—	—	—	—
7	.027	.037	.046	.055	0.063	0.071	0.078	—	—	—	—	—
8	.035	.048	.061	.072	.083	.093	.102	0.110	—	—	—	—
9	.045	.061	.077	.092	.106	.119	.130	.141	0.150	0.157	—	—
10	.056	.076	.096	.114	.132	.147	.162	.174	.186	.195	—	—
11	.068	.092	.116	.139	.160	.179	.197	.212	.226	.238	0.248	0.256
12	.081	.111	.139	.166	.191	.214	.235	.254	.270	.284	.296	.306
13	.096	.130	.164	.196	.226	.253	.277	.299	.318	.335	.349	.361
14	.112	.152	.191	.228	.263	.294	.323	.349	.371	.391	.407	.420
15	.129	.175	.221	.264	.303	.340	.373	.402	.428	.451	.469	.485
16	.147	.200	.252	.301	.347	.388	.426	.460	.490	.515	.537	.554
17	.167	.227	.286	.342	.393	.441	.483	.522	.555	.584	.609	.629
18	.188	.256	.322	.385	.443	.496	.545	.588	.626	.658	.686	.708
19	.210	.287	.361	.431	.496	.556	.610	.658	.700	.737	.768	.793
20	.234	.319	.402	.480	.552	.619	.679	.732	.780	.821	.855	.883
21	.259	.354	.445	.532	.612	.685	.752	.811	.864	.909	.947	.978
22	.286	.390	.491	.586	.675	.756	.829	.895	.952	1.002	1.044	1.078
23	.314	.428	.539	.644	.741	.830	.910	.982	1.046	1.101	1.147	1.184
24	.344	.468	.590	.704	.811	.908	.996	1.075	1.144	1.204	1.255	1.296

Table 3. — Gross volume in cubic feet

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.9	1.2	1.5	1.8	2.1	—	—	—	—	—	—	—	—	—	—
6	1.3	1.8	2.2	2.7	3.1	3.5	3.8	—	—	—	—	—	—	—	—
7	1.8	2.4	3.1	3.6	4.2	4.8	5.3	5.7	6.2	—	—	—	—	—	—
8	2.4	3.2	4.0	4.8	5.5	6.2	6.9	7.5	8.1	8.6	9.1	—	—	—	—
9	3.1	4.1	5.1	6.1	7.0	7.9	8.8	9.6	10.3	10.9	11.5	12.1	12.6	—	—
10	3.8	5.0	6.3	7.6	8.7	9.9	10.9	11.9	12.8	13.6	14.3	15.0	15.6	—	—
11	4.6	6.1	7.7	9.2	10.6	12.0	13.3	14.4	15.5	16.5	17.4	18.2	18.9	19.6	20.1
12	5.5	7.3	9.2	11.0	12.7	14.3	15.9	17.3	18.6	19.8	20.8	21.8	22.7	23.4	24.0
13	6.5	8.7	10.8	13.0	15.0	16.9	18.7	20.4	21.9	23.3	24.6	25.7	26.7	27.6	28.3
14	7.6	10.1	12.6	15.1	17.5	19.7	21.8	23.7	25.5	27.2	28.6	30.0	31.1	32.2	33.0
15	8.7	11.6	14.6	17.4	20.2	22.7	25.1	27.4	29.4	31.3	33.0	34.6	35.9	37.1	38.1
16	10.0	13.3	16.7	19.9	23.1	26.0	28.7	31.3	33.7	35.8	37.8	39.5	41.1	42.4	43.5
17	11.3	15.1	18.9	22.6	26.2	29.5	32.6	35.5	38.2	40.6	42.8	44.8	46.6	48.1	49.4
18	12.8	17.0	21.3	25.5	29.5	33.2	36.7	40.0	43.0	45.8	48.3	50.5	52.5	54.2	55.6
19	14.3	19.0	23.8	28.5	33.0	37.2	41.1	44.8	48.2	51.2	54.0	56.5	58.8	60.7	62.3
20	15.9	21.2	26.5	31.8	36.7	41.4	45.8	49.9	53.6	57.1	60.2	63.0	65.4	67.5	69.3
21	17.6	23.5	29.4	35.2	40.7	45.9	50.7	55.2	59 4	63.2	66.6	69.7	72.5	74 8	76.8
22	19.5	25.9	32.4	38.8	44.9	50.6	55.9	60.9	65.5	69.7	73.5	76.9	79.9	82.5	84.7
23	21.4	28.4	35.6	42.6	49.3	55.5	61.4	66.9	71.9	76.5	80.7	84.4	87.7	90.6	93.0
24	23.4	31.1	39.0	46.6	53.9	60.8	67.2	73.2	78.7	83.7	88.3	92.4	96.0	99.1	101.8

Table 4. — Gross volume in cubic feet

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	1.1	1.5	1.8	—	—	—	—	—	—	—	—	—
6	1.6	2.1	2.7	3.2	—	—	—	—	—	—	—	—
7	2.1	2.9	3.6	4.4	5.0	5.6	6.2	—	—	—	—	—
8	2.8	3.8	4.8	5.7	6.6	7.4	8.1	8.7	—	—	—	—
9	3.6	4.8	6.1	7.3	8.4	9.4	10.3	11.1	11.8	12.4	—	—
10	4.4	6.0	7.6	9.0	10.4	11.6	12.8	13.8	14.7	15.4	—	—
11	5.4	7.3	9.2	11.0	12.6	14.2	15.5	16.8	17.8	18.8	19.6	20.2
12	6.4	8.7	11.0	13.1	15.1	16.9	18.6	20.0	21.3	22.4	23.4	24.2
13	7.6	10.3	13.0	15.5	17.8	20.0	21.9	23.6	25.2	26.5	27.6	28.5
14	8.8	12.0	15.1	18.0	20.8	23.3	25.5	27.5	29.3	30.9	32.2	33.2
15	10.2	13.8	17.4	20.8	24.0	26.8	29.4	31.8	33.8	35.6	37.1	38.3
16	11.6	15.8	19.9	23.8	27.4	30.7	33.7	36.3	38.7	40.7	42.4	43.8
17	13.2	18.0	22.6	27.0	31.1	34.8	38.2	41.2	43.9	46.2	48.1	49.7
18	14.8	20.2	25.5	30.4	35.0	39.2	43.0	46.4	49.4	52.0	54.2	56.0
19	16.6	22.6	28.5	34.1	39.2	43.9	48.2	52.0	55.3	58.2	60.7	62.6
20	18.5	25.2	31.8	37.9	43.6	48.9	53.6	57.9	61.6	64.8	67.5	69.7
21	20.5	27.9	35.2	42.0	48.3	54.1	59.4	64.1	68.2	71.8	74.8	77.3
22	22.6	30.8	38.8	46.3	53.3	59.7	65.5	70.7	75.2	79.2	82.5	85.2
23	24.8	33.8	42.6	50.9	58.5	65.6	71.9	77.6	82.6	87.0	90.6	93.6
24	27.2	37.0	46.6	55.6	64.0	71.7	78.7	84.9	90.4	95.1	99.1	102.3

Table 5. — Gross volume in cubic meters

Dbh		Merchantable height in feet (first line) and meters (second line)														
Inches	Centimeters	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
		2.44	3.66	4.88	6.10	7.32	8.53	9.75	10.97	12.19	13.41	14.63	15.85	17.07	18.29	19.51
5	12.70	0.027	0.035	0.042	0.051	0.060	—	—	—	—	—	—	—	—	—	—
6	15.24	.038	.051	.062	.075	.086	0.097	0.108	—	—	—	—	—	—	—	—
7	17.78	.051	.069	.086	.102	.117	.133	.148	0.161	0.173	—	—	—	—	—	—
8	20.32	.066	.088	.113	.135	.155	.175	.192	.210	.226	0.241	0.254	—	—	—	—
9	22.86	.086	.113	.142	.170	.196	.223	.246	.268	.288	.307	.323	0.338	0.352	—	—
10	25.40	.106	.142	.177	.212	.246	.277	.305	.332	.358	.380	.400	.420	.436	—	—
11	27.94	.128	.173	.215	.256	.299	.336	.372	.405	.436	.462	.489	.511	.531	0.549	0.562
12	30.48	.155	.206	.257	.307	.356	.400	.445	.484	.520	.553	.584	.611	.635	.650	.672
13	33.02	.181	.241	.303	.363	.420	.473	.524	.571	.613	.653	.688	.719	.748	.772	.794
14	35.56	.212	.283	.354	.422	.489	.551	.611	.664	.714	.761	.803	.838	.872	.900	.925
15	38.10	.246	.325	.407	.489	.564	.637	.703	.768	.825	.878	.925	.969	1.006	1.037	1.066
16	40.64	.281	.372	.467	.557	.646	.728	.805	.876	.942	1.002	1.057	1.106	1.150	1.188	1.219
17	43.18	.319	.422	.529	.633	.732	.825	.914	.995	1.068	1.137	1.199	1.256	1.305	1.347	1.383
18	45.72	.358	.476	.597	.712	.825	.929	1.029	1.119	1.206	1.281	1.352	1.413	1.469	1.517	1.557
19	48.26	.400	.533	.668	.799	.922	1.042	1.152	1.254	1.349	1.436	1.513	1.584	1.646	1.699	1.743
20	50.80	.447	.593	.743	.889	1.029	1.159	1.283	1.396	1.502	1.597	1.686	1.763	1.832	1.891	1.942
21	53.34	.493	.657	.823	.984	1.139	1.285	1.420	1.546	1.663	1.770	1.867	1.953	2.028	2.095	2.150
22	55.88	.544	.723	.907	1.086	1.256	1.416	1.566	1.705	1.834	1.951	2.057	2.152	2.236	2.309	2.371
23	58.42	.596	.796	.998	1.192	1.378	1.555	1.719	1.874	2.013	2.143	2.261	2.365	2.458	2.537	2.604
24	60.96	.655	.869	1.091	1.305	1.509	1.701	1.882	2.048	2.203	2.345	2.473	2.586	2.688	2.776	2.849

Table 6. — Gross volume in cubic meters

Dbh		Merchantable height in feet (first line) and meters (second line)											
Inches	Centimeters	10	15	20	25	30	35	40	45	50	55	60	65
		3.05	4.57	6.10	7.62	9.14	10.67	12.19	13.72	15.24	16.76	18.29	19.81
5	12.70	0.031	0.042	0.051	—	—	—	—	—	—	—	—	—
6	15.24	.044	.060	.075	0.088	—	—	—	—	—	—	—	—
7	17.78	.060	.082	.102	.122	0.139	0.157	0.173	—	—	—	—	—
8	20.32	.077	.106	.135	.159	.184	.206	.226	0.243	—	—	—	—
9	22.86	.100	.135	.170	.204	.234	.263	.288	.312	0.332	0.347	—	—
10	25.40	.124	.168	.212	.252	.292	.325	.358	.385	.411	.431	—	—
11	27.94	.150	.204	.256	.307	.354	.396	.436	.469	.500	.526	0.549	0.566
12	30.48	.179	.246	.307	.367	.422	.473	.520	.562	.597	.628	.650	.677
13	33.02	.212	.288	.363	.434	.500	.560	.613	.661	.703	.741	.772	.799
14	35.56	.248	.336	.422	.504	.582	.650	.714	.772	.821	.865	.900	.929
15	38.10	.285	.387	.489	.584	.670	.752	.825	.889	.947	.998	1.037	1.073
16	40.64	.325	.442	.557	.666	.768	.858	.942	1.018	1.084	1.139	1.188	1.225
17	43.18	.369	.502	.633	.757	.869	.975	1.068	1.155	1.228	1.292	1.347	1.391
18	45.72	.416	.566	.712	.852	.980	1.097	1.206	1.301	1.385	1.455	1.517	1.566
19	48.26	.465	.635	.799	.953	1.097	1.230	1.349	1.455	1.548	1.630	1.699	1.754
20	50.80	.518	.706	.889	1.062	1.221	1.369	1.502	1.619	1.725	1.816	1.891	1.953
21	53.34	.573	.783	.984	1.177	1.354	1.515	1.663	1.794	1.911	2.011	2.095	2.163
22	55.88	.633	.863	1.086	1.296	1.493	1.672	1.834	1.980	2.106	2.216	2.309	2.385
23	58.42	.695	.947	1.192	1.425	1.639	1.836	2.013	2.172	2.314	2.435	2.537	2.619
24	60.96	.761	1.035	1.305	1.557	1.794	2.008	2.203	2.378	2.531	2.663	2.776	2.867

Table 7. — Gross weight in tons for soft hardwoods

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.026	0.035	0.044	0.052	0.061	—	—	—	—	—	—	—	—	—	—
6	.038	.051	.064	.076	.088	0.099	0.110	—	—	—	—	—	—	—	—
7	.052	.069	.087	.104	.120	.136	.150	0.163	0.175	—	—	—	—	—	—
8	.068	.091	.114	.136	.158	.178	.197	.214	.230	0.245	0.259	—	—	—	—
9	.087	.116	.145	.174	.201	.226	.250	.273	.293	.312	.329	0.344	0.357	—	—
10	.108	.144	.180	.215	.249	.281	.310	.338	.364	.387	.408	.427	.444	—	—
11	.131	.175	.219	.262	.303	.341	.378	.411	.442	.470	.496	.519	.539	0.557	0.572
12	.157	.209	.262	.313	.362	.408	.452	.492	.529	.563	.593	.621	.645	.666	.684
13	.185	.246	.309	.369	.427	.482	.533	.580	.624	.664	.700	.732	.761	.786	.807
14	.216	.287	.360	.430	.498	.561	.621	.676	.727	.773	.816	.853	.887	.916	.940
15	.249	.331	.415	.497	.574	.648	.716	.780	.839	.892	.941	.985	1.023	1.056	1.085
16	.285	.379	.475	.568	.657	.740	.819	.892	.959	1.020	1.076	1.126	1.170	1.208	1.240
17	.323	.430	.538	.644	.745	.840	.929	1.011	1.088	1.157	1.220	1.277	1.327	1.370	1.407
18	.364	.484	.607	.726	.839	.946	1.046	1.139	1.225	1.304	1.375	1.438	1.495	1.543	1.585
19	.407	.542	.679	.812	.939	1.059	1.171	1.276	1.372	1.460	1.539	1.610	1.673	1.728	1.774
20	.454	.603	.756	.904	1.046	1.179	1.304	1.420	1.527	1.625	1.714	1.793	1.863	1.924	1.975
21	.502	.668	.837	1.002	1.158	1.306	1.445	1.573	1.692	1.800	1.898	1.986	2.064	2.131	2.188
22	.554	.737	.923	1.105	1.277	1.440	1.593	1.735	1.865	1.985	2.093	2.190	2.276	2.350	2.413
23	.608	.809	1.014	1.213	1.403	1.582	1.749	1.905	2.048	2.180	2.299	2.405	2.499	2.580	2.649
24	.666	.885	1.109	1.327	1.535	1.730	1.914	2.084	2.241	2.385	2.515	2.631	2.734	2.823	2.898

Table 8. — Gross weight in tons for soft hardwoods

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.031	0.042	0.052	—	—	—	—	—	—	—	—	—
6	.044	.060	.076	0.091	—	—	—	—	—	—	—	—
7	.061	.083	.104	.124	0.143	0.160	0.175	—	—	—	—	—
8	.080	.108	.136	.163	.187	.210	.230	0.249	—	—	—	—
9	.101	.138	.174	.207	.238	.267	.293	.316	0.337	0.354	—	—
10	.125	.171	.215	.257	.296	.331	.364	.392	.418	.440	—	—
11	.153	.208	.262	.313	.360	.403	.442	.477	.508	.535	0.557	0.575
12	.183	.249	.313	.374	.430	.482	.529	.571	.608	.639	.666	.688
13	.215	.293	.369	.441	.508	.568	.624	.673	.717	.754	.786	.811
14	.251	.342	.430	.514	.592	.663	.727	.784	.835	.879	.916	.946
15	.289	.394	.497	.593	.682	.764	.839	.905	.963	1.014	1.056	1.091
16	.331	.451	.568	.678	.780	.874	.959	1.035	1.101	1.159	1.208	1.247
17	.375	.511	.644	.769	.885	.991	1.088	1.174	1.249	1.315	1.370	1.415
18	.423	.576	.726	.866	.997	1.117	1.225	1.322	1.408	1.481	1.543	1.594
19	.473	.645	.812	.970	1.116	1.250	1.372	1.480	1.576	1.658	1.728	1.784
20	.527	.718	.904	1.080	1.243	1.392	1.527	1.648	1.754	1.846	1.924	1.986
21	.584	.795	1.002	1.196	1.377	1.542	1.692	1.826	1.943	2.045	2.131	2.200
22	.644	.877	1.105	1.319	1.518	1.700	1.865	2.013	2.143	2.255	2.350	2.426
23	.707	.963	1.213	1.449	1.667	1.867	2.048	2.211	2.353	2.477	2.580	2.665
24	.773	1.054	1.327	1.585	1.824	2.043	2.241	2.418	2.575	2.709	2.823	2.915

Table 9. — Gross weight in tons for hard hardwoods

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.029	0.039	0.049	0.058	0.067	—	—	—	—	—	—	—	—	—	—
6	.042	.056	.071	.084	.098	0.110	0.122	—	—	—	—	—	—	—	—
7	.058	.077	.097	.115	.134	.151	.167	0.181	0.195	—	—	—	—	—	—
8	.076	.101	.127	.152	.175	.198	.219	.238	.256	0.272	0.287	—	—	—	—
9	.097	.129	.161	.193	.223	.251	.278	.303	.326	.346	.365	0.382	0.397	—	—
10	.120	.160	.200	.239	.277	.312	.345	.376	.404	.430	.453	.474	.493	—	—
11	.146	.194	.243	.291	.336	.379	.420	.457	.491	.523	.551	.577	.599	0.619	0.635
12	.175	.232	.291	.348	.402	.454	.502	.546	.588	.625	.659	.690	.717	.740	.760
13	.206	.274	.343	.410	.475	.535	.592	.644	.693	.737	.778	.814	.845	.873	.896
14	.240	.319	.400	.478	.553	.624	.690	.751	.808	.859	.906	.948	.985	1.017	1.045
15	.277	.368	.461	.552	.638	.719	.796	.866	.932	.991	1.045	1.094	1.137	1.174	1.205
16	.316	.421	.527	.631	.730	.823	.910	.991	1.065	1.134	1.195	1.251	1.300	1.342	1.378
17	.359	.477	.598	.716	.828	.933	1.032	1.124	1.208	1.286	1.356	1.419	1.474	1.522	1.563
18	.404	.538	.674	.806	.932	1.051	1.163	1.266	1.361	1.449	1.528	1.598	1.661	1.715	1.761
19	.453	.602	.754	.903	1.044	1.177	1.301	1.417	1.524	1.622	1.710	1.789	1.859	1.920	1.971
20	.504	.670	.840	1.005	1.162	1.310	1.449	1.578	1.697	1.806	1.904	1.992	2.070	2.137	2.194
21	.558	.742	.931	1.113	1.287	1.451	1.605	1.748	1.880	2.000	2.109	2.207	2.293	2.368	2.431
22	.616	.819	1.026	1.227	1.419	1.601	1.770	1.927	2.073	2.205	2.326	2.433	2.529	2.611	2.681
23	.676	.899	1.127	1.348	1.559	1.758	1.944	2.117	2.276	2.422	2.554	2.672	2.777	2.867	2.944
24	.740	.984	1.233	1.475	1.705	1.923	2.126	2.315	2.490	2.649	2.794	2.923	3.038	3.137	3.220

Table 10. — Gross weight in tons for hard hardwoods

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.034	0.046	0.058	—	—	—	—	—	—	—	—	—
6	.049	.067	.084	0.101	—	—	—	—	—	—	—	—
7	.067	.092	.115	.138	0.159	0.178	0.195	—	—	—	—	—
8	.088	.120	.152	.181	.208	.233	.256	0.276	—	—	—	—
9	.112	.153	.193	.230	.265	.297	.326	.351	0.374	0.394	—	—
10	.139	.190	.239	.286	.329	.368	.404	.436	.464	.488	—	—
11	.170	.231	.291	.347	.400	.448	.491	.530	.564	.594	0.619	0.639
12	.203	.276	.348	.416	.478	.536	.588	.634	.675	.710	.740	.764
13	.239	.326	.410	.490	.564	.632	.693	.748	.796	.838	.873	.901
14	.279	.380	.478	.571	.657	.736	.808	.872	.928	.977	1.017	1.051
15	.322	.438	.552	.659	.758	.849	.932	1.005	1.070	1.127	1.174	1.212
16	.368	.501	.631	.753	.867	.971	1.065	1.150	1.224	1.288	1.342	1.386
17	.417	.568	.716	.855	.983	1.101	1.208	1.304	1.388	1.461	1.522	1.572
18	.470	.640	.806	.963	1.108	1.241	1.361	1.469	1.564	1.646	1.715	1.771
19	.526	.717	.903	1.078	1.240	1.389	1.524	1.645	1.751	1.843	1.920	1.982
20	.586	.798	1.005	1.200	1.381	1.547	1.697	1.831	1.949	2.052	2.137	2.207
21	.649	.884	1.113	1.329	1.530	1.713	1.880	2.028	2.159	2.273	2.368	2.445
22	.715	.975	1.227	1.466	1.687	1.889	2.073	2.237	2.381	2.506	2.611	2.696
23	.786	1.070	1.348	1.610	1.852	2.075	2.276	2.456	2.615	2.752	2.867	2.961
24	.859	1.171	1.475	1.761	2.026	2.270	2.490	2.687	2.861	3.010	3.137	3.239

Table 11. — Gross weight in metric tons for soft hardwoods

Dbh		Merchantable height in feet (first line) and meters (second line)														
Inches	Centimeters	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
		2.44	3.66	4.88	6.10	7.32	8.53	9.75	10.97	12.19	13.41	14.63	15.85	17.07	18.29	19.51
5	12.70	0.024	0.033	0.039	0.047	0.055	—	—	—	—	—	—	—	—	—	—
6	15.24	.035	.047	.057	.069	.080	0.090	0.100	—	—	—	—	—	—	—	—
7	17.78	.047	.063	.080	.094	.108	.122	.137	0.149	0.159	—	—	—	—	—	—
8	20.32	.061	.082	.104	.124	.143	.161	.177	.194	.208	0.222	0.235	—	—	—	—
9	22.86	.080	.104	.131	.157	.182	.206	.226	.247	.265	.284	.298	0.312	0.324	—	—
10	25.40	.098	.131	.163	.196	.226	.255	.282	.306	.330	.351	.369	.388	.402	—	—
11	27.94	.118	.159	.198	.237	.275	.310	.343	.373	.402	.426	.451	.471	.490	0.506	0.518
12	30.48	.143	.190	.237	.284	.328	.369	.410	.447	.479	.510	.539	.563	.585	.604	.620
13	33.02	.167	.222	.279	.335	.388	.437	.483	.526	.565	.602	.634	.663	.690	.712	.732
14	35.56	.196	.261	.326	.390	.451	.508	.563	.612	.659	.702	.741	.773	.804	.830	.853
15	38.10	.226	.300	.375	.451	.520	.588	.649	.708	.761	.810	.853	.894	.928	.957	.983
16	40.64	.259	.343	.430	.514	.596	.671	.743	.808	.869	.924	.975	1.020	1.061	1.095	1.124
17	43.18	.294	.390	.488	.583	.675	.761	.843	.918	.985	1.049	1.106	1.159	1.204	1.242	1.275
18	45.72	.330	.439	.551	.657	.761	.857	.949	1.052	1.112	1.181	1.246	1.304	1.355	1.399	1.436
19	48.26	.369	.492	.616	.736	.851	.961	1.063	1.157	1.244	1.324	1.395	1.461	1.518	1.567	1.608
20	50.80	.412	.547	.685	.820	.949	1.069	1.183	1.287	1.385	1.473	1.554	1.626	1.689	1.744	1.791
21	53.34	.455	.606	.759	.908	1.051	1.185	1.310	1.426	1.534	1.632	1.722	1.801	1.871	1.932	1.983
22	55.88	.502	.667	.836	1.002	1.159	1.306	1.444	1.573	1.691	1.799	1.897	1.985	2.062	2.130	2.187
23	58.42	.551	.734	.920	1.100	1.271	1.434	1.585	1.728	1.856	1.977	2.085	2.181	2.266	2.340	2.401
24	60.96	.604	.802	1.006	1.204	1.391	1.569	1.736	1.889	2.032	2.162	2.281	2.385	2.479	2.560	2.628

Table 12. — Gross weight in metric tons for soft hardwoods

Dbh		Merchantable height in feet (first line) and meters (second line)											
Inches	Centimeters	10	15	20	25	30	35	40	45	50	55	60	65
		3.05	4.57	6.10	7.62	9.14	10.67	12.19	13.72	15.24	16.76	18.29	19.81
5	12.70	0.029	0.039	0.047	—	—	—	—	—	—	—	—	—
6	15.24	.041	.055	.069	0.082	—	—	—	—	—	—	—	—
7	17.78	.055	.075	.094	.112	0.129	0.145	0.159	—	—	—	—	—
8	20.32	.071	.098	.124	.147	.169	.190	.208	0.224	—	—	—	—
9	22.86	.092	.124	.157	.188	.216	.243	.265	.288	0.306	0.320	—	—
10	25.40	.114	.155	.196	.233	.269	.300	.330	.355	.379	.398	—	—
11	27.94	.139	.188	.237	.284	.326	.365	.402	.432	.461	.486	0.506	0.522
12	30.48	.165	.226	.284	.339	.390	.437	.479	.518	.551	.579	.604	.624
13	33.02	.196	.265	.335	.400	.461	.516	.565	.610	.649	.683	.712	.736
14	35.56	.228	.310	.390	.465	.537	.600	.659	.712	.757	.798	.830	.857
15	38.10	.263	.357	.451	.539	.618	.694	.761	.820	.873	.920	.957	.989
16	40.64	.300	.408	.514	.614	.708	.792	.869	.938	1.000	1.051	1.095	1.130
17	43.18	.341	.463	.583	.698	.802	.900	.985	1.065	1.132	1.191	1.242	1.283
18	45.72	.384	.522	.657	.785	.904	1.012	1.112	1.200	1.277	1.342	1.399	1.444
19	48.26	.482	.585	.736	.879	1.012	1.134	1.244	1.342	1.428	1.503	1.567	1.618
20	50.80	.477	.651	.820	.979	1.126	1.263	1.385	1.493	1.591	1.675	1.744	1.801
21	53.34	.528	.722	.908	1.085	1.248	1.397	1.534	1.654	1.763	1.854	1.932	1.995
22	55.88	.583	.796	1.002	1.195	1.377	1.542	1.691	1.826	1.942	2.044	2.130	2.199
23	58.42	.641	.873	1.100	1.314	1.512	1.693	1.856	2.003	2.134	2.246	2.340	2.415
24	60.96	.702	.955	1.204	1.436	1.654	1.852	2.032	2.193	2.334	2.456	2.560	2.644

Table 13. — Gross weight in metric tons for hard hardwoods

Dbh		Merchantable height in feet (first line) and meters (second line)														
Inches	Centimeters	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
		2.44	3.66	4.88	6.10	7.32	8.53	9.75	10.97	12.19	**13.41**	14.63	15.85	17.07	18.29	19.51
5	12.70	0.027	0.036	0.043	0.052	0.061	—	—	—	—	—	—	—	—	—	—
6	15.24	.039	.052	.064	.077	.089	0.100	0.111	—	—	—	—	—	—	—	—
7	17.78	.052	.070	.089	.104	.120	.136	.152	0.166	0.177	—	—	—	—	—	—
8	20.32	.068	.091	.116	.138	.159	.179	.197	.216	.232	0.247	0.261	—	—	—	—
9	22.86	.089	.116	.145	.175	.202	.229	.252	.275	.295	.316	.331	0.347	0.361	—	—
10	25.40	.109	.145	.182	.218	.252	.284	.313	.341	.368	.390	.411	.431	.447	—	—
11	27.94	.132	.177	.220	.263	.306	.345	.381	.415	.447	.474	.502	.524	.545	0.563	0.577
12	30.48	.159	.211	.263	.316	.365	.411	.456	.497	.533	.568	.599	.627	.651	.672	.690
13	33.02	.186	.247	.311	.372	.431	.486	.538	.586	.629	.670	.706	.738	.767	.792	.815
14	35.56	.218	.291	.363	.434	.502	.565	.627	.681	.733	.781	.824	.860	.894	.924	.949
15	38.10	.252	.334	.418	.502	.579	.654	.722	.788	.847	.901	.949	.994	1.033	1.065	1.094
16	40.64	.288	.381	.479	.572	.663	.747	.826	.899	.967	1.028	1.085	1.135	1.180	1.219	1.251
17	43.18	.327	.434	.543	.649	.751	.847	.938	1.022	1.096	1.167	1.230	1.289	1.339	1.382	1.419
18	45.72	.368	.488	.613	.731	.847	.953	1.056	1.149	1.237	1.314	1.387	1.451	1.507	1.557	1.598
19	48.26	.411	.547	.686	.819	.947	1.069	1.183	1.287	1.385	1.473	1.553	1.625	1.689	1.743	1.789
20	50.80	.459	.608	.763	.913	1.056	1.189	1.317	1.432	1.541	1.639	1.730	1.809	1.880	1.941	1.993
21	53.34	.506	.674	.844	1.010	1.169	1.319	1.457	1.587	1.707	1.816	1.916	2.004	2.082	2.150	2.206
22	55.88	.558	.742	.931	1.115	1.289	1.453	1.607	1.750	1.882	2.002	2.111	2.209	2.295	2.370	2.433
23	58.42	.613	.817	1.024	1.224	1.414	1.596	1.764	1.923	2.066	2.200	2.320	2.427	2.522	2.604	2.672
24	60.96	.672	.892	1.119	1.339	1.548	1.746	1.932	2.102	2.261	2.406	2.538	2.654	2.758	2.849	2.924

Table 14. — Gross weight in metric tons for hard hardwoods

Dbh		Merchantable height in feet (first line) and meters (second line)											
Inches	Centimeters	10	15	20	25	30	35	40	45	50	55	60	65
		3.05	4.57	6.10	7.62	9.14	10.67	12.19	13.72	15.24	16.76	18.29	19.81
5	12.70	0.032	0.043	0.052	—	—	—	—	—	—	—	—	—
6	15.24	.045	.061	.077	0.091	—	—	—	—	—	—	—	—
7	17.78	.061	.084	.104	.125	0.143	0.161	0.177	—	—	—	—	—
8	20.32	.079	.109	.138	.163	.188	.211	.232	0.250	—	—	—	—
9	22.86	.102	.138	.175	.209	.241	.270	.295	.320	0.341	0.356	—	—
10	25.40	.127	.173	.218	.259	.300	.334	.368	.395	.422	.443	—	—
11	27.94	.154	.209	.263	.316	.363	.406	.447	.481	.513	.540	0.563	0.581
12	30.48	.184	.252	.316	.377	.434	.486	.533	.577	.613	.645	.672	.695
13	33.02	.218	.295	.372	.445	.513	.574	.629	.679	.722	.760	.792	.819
14	35.56	.254	.345	.434	.518	.597	.667	.733	.792	.842	.888	.924	.953
15	38.10	.293	.397	.502	.599	.688	.772	.847	.913	.972	1.024	1.065	1.101
16	40.64	.334	.454	.572	.683	.788	.881	.967	1.044	1.112	1.169	1.219	1.258
17	43.18	.379	.515	.649	.776	.892	1.001	1.096	1.185	1.260	1.326	1.382	1.428
18	45.72	.427	.581	.731	.874	1.006	1.126	1.237	1.335	1.421	1.494	1.557	1.607
19	48.26	.477	.651	.819	.978	1.126	1.262	1.385	1.494	1.589	1.673	1.743	1.800
20	50.80	.531	.724	.913	1.090	1.253	1.405	1.541	1.662	1.771	1.864	1.941	2.004
21	53.34	.588	.804	1.010	1.208	1.389	1.555	1.707	1.841	1.961	2.063	2.150	2.220
22	55.88	.649	.885	1.115	1.330	1.532	1.716	1.882	2.032	2.161	2.275	2.370	2.447
23	58.42	.713	.972	1.224	1.462	1.682	1.884	2.066	2.229	2.374	2.499	2.604	2.688
24	60.96	.781	1.062	1.339	1.598	1.841	2.061	2.261	2.440	2.597	2.733	2.849	2.942

APPENDIX B

Pulpwood Values

Table						
15, 16	Pulpwood	values	at	$1.00	per	cord
17, 18	”	”	”	1.50	”	”
19, 20	”	”	”	2.00	”	”
21, 22	”	”	”	2.50	”	”
23, 24	”	”	”	3.00	”	”
25, 26	”	”	”	4.00	”	”
27, 28	”	”	”	5.00	”	”
29, 30	”	”	”	7.50	”	”
31, 32	”	”	”	10.00	”	”
33, 34	”	”	”	15.00	”	”
35, 36	”	”	”	20.00	”	”
37, 38	”	”	”	25.00	”	”

All values are to top diameters that are variable, but not less than 4.0 inches.

Odd-numbered tables are for 4-foot merchantable lengths.

Even-numbered tables are for 5-foot merchantable lengths.

Table 15. — Pulpwood values at $1.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.01	0.02	0.02	0.02	0.03	—	—	—	—	—	—	—	—	—	—
6	.02	.02	.03	.03	.04	0.04	0.05	—	—	—	—	—	—	—	—
7	.02	.03	.04	.05	.05	.06	.07	0.07	0.08	—	—	—	—	—	—
8	.03	.04	.05	.06	.07	.08	.09	.10	.10	0.11	0.11	—	—	—	—
9	.04	.05	.06	.08	.09	.10	.11	.12	.13	.14	.15	0.15	0.16	—	—
10	.05	.06	.08	.10	.11	.12	.14	.15	.16	.17	.18	.19	.20	—	—
11	.06	.08	.10	.12	.13	.15	.17	.18	.20	.21	.22	.23	.24	0.25	0.25
12	.07	.09	.12	.14	.16	.18	.20	.22	.24	.25	.26	.28	.29	.30	.30
13	.08	.11	.14	.16	.19	.21	.24	.26	.28	.29	.31	.33	.34	.35	.36
14	.10	.13	.16	.19	.22	.25	.28	.30	.32	.34	.36	.38	.39	.41	.42
15	.11	.15	.18	.22	.26	.29	.32	.35	.37	.40	.42	.44	.45	.47	.48
16	.13	.17	.21	.25	.29	.33	.36	.40	.43	.45	.48	.50	.52	.54	.55
17	.14	.19	.24	.29	.33	.37	.41	.45	.48	.51	.54	.57	.59	.61	.63
18	.16	.22	.27	.32	.37	.42	.47	.51	.54	.58	.61	.64	.66	.69	.70
19	.18	.24	.30	.36	.42	.47	.52	.57	.61	.65	.68	.72	.74	.77	.79
20	.20	.27	.34	.40	.46	.52	.58	.63	.68	.72	.76	.80	.83	.85	.88
21	.22	.30	.37	.45	.51	.58	.64	.70	.75	.80	.84	.88	.92	.95	.97
22	.25	.33	.41	.49	.57	.64	.71	.77	.83	.88	.93	.97	1.01	1.04	1.07
23	.27	.36	.45	.54	.62	.70	.78	.85	.91	.97	1.02	1.07	1.11	1.15	1.18
24	.30	.39	.49	.59	.68	.77	.85	.93	1.00	1.06	1.12	1.17	1.22	1.26	1.29

Table 16.—Pulpwood values at $1.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.01	0.02	0.02	—	—	—	—	—	—	—	—	—
6	.02	.03	.03	0.04	—	—	—	—	—	—	—	—
7	.03	.04	.05	.06	0.06	0.07	0.08	—	—	—	—	—
8	.04	.05	.06	.07	.08	.09	.10	0.11	—	—	—	—
9	.04	.06	.08	.09	.11	.12	.13	.14	0.15	0.16	—	—
10	.06	.08	.10	.11	.13	.15	.16	.17	.19	.20	—	—
11	.07	.09	.12	.14	.16	.18	.20	.21	.23	.24	0.25	0.26
12	.08	.11	.14	.17	.19	.21	.24	.25	.27	.28	.30	.31
13	.10	.13	.16	.20	.23	.25	.28	.30	.32	.34	.35	.36
14	.11	.15	.19	.23	.26	.29	.32	.35	.37	.39	.41	.42
15	.13	.18	.22	.26	.30	.34	.37	.40	.43	.45	.47	.48
16	.15	.20	.25	.30	.35	.39	.43	.46	.49	.52	.54	.55
17	.17	.23	.29	.34	.39	.44	.48	.52	.56	.58	.61	.63
18	.19	.26	.32	.39	.44	.50	.54	.59	.63	.66	.69	.71
19	.21	.29	.36	.43	.50	.56	.61	.66	.70	.74	.77	.79
20	.23	.32	.40	.48	.55	.62	.68	.73	.78	.82	.85	.88
21	.26	.35	.45	.53	.61	.69	.75	.81	.86	.91	.95	.98
22	.29	.39	.49	.59	.67	.76	.83	.89	.95	1.00	1.04	1.08
23	.31	.43	.54	.64	.74	.83	.91	.98	1.05	1.10	1.15	1.18
24	.34	.47	.59	.70	.81	.91	1.00	1.08	1.14	1.20	1.26	1.30

Table 17. — Pulpwood values at $1.50 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.02	0.02	0.03	0.03	0.04	—	—	—	—	—	—	—	—	—	—
6	.03	.03	.04	.05	.06	0.07	0.07	—	—	—	—	—	—	—	—
7	.03	.05	.06	.07	.08	.09	.10	0.11	0.12	—	—	—	—	—	—
8	.05	.06	.08	.09	.11	.12	.13	.14	.15	0.16	0.17	—	—	—	—
9	.06	.08	.10	.12	.13	.15	.17	.18	.20	.21	.22	0.23	0.24	—	—
10	.07	.10	.12	.14	.17	.19	.21	.23	.24	.26	.27	.28	.30	—	—
11	.09	.12	.15	.17	.20	.23	.25	.27	.29	.31	.33	.35	.36	0.37	0.38
12	.10	.14	.17	.21	.24	.27	.30	.33	.35	.38	.40	.41	.43	.44	.46
13	.12	.16	.21	.25	.28	.32	.36	.39	.42	.44	.47	.49	.51	.52	.54
14	.14	.19	.24	.29	.33	.37	.41	.45	.48	.52	.54	.57	.59	.61	.63
15	.17	.22	.28	.33	.38	.43	.48	.52	.56	.59	.63	.66	.68	.70	.72
16	.19	.25	.32	.38	.44	.49	.55	.59	.64	.68	.72	.75	.78	.81	.83
17	.22	.29	.36	.43	.50	.56	.62	.67	.73	.77	.81	.85	.88	.91	.94
18	.24	.32	.40	.48	.56	.63	.70	.76	.82	.87	.92	.96	1.00	1.03	1.06
19	.27	.36	.45	.54	.63	.71	.78	.85	.91	.97	1.03	1.07	1.12	1.15	1.18
20	.30	.40	.50	.60	.70	.79	.87	.95	1.02	1.08	1.14	1.20	1.24	1.28	1.32
21	.33	.45	.56	.67	.77	.87	.96	1.05	1.13	1.20	1.27	1.32	1.38	1.42	1.46
22	.37	.49	.62	.74	.85	.96	1.06	1.16	1.24	1.32	1.40	1.46	1.52	1.57	1.61
23	.41	.54	.68	.81	.94	1.05	1.17	1.27	1.37	1.45	1.53	1.60	1.67	1.72	1.77
24	.44	.59	.74	.89	1.02	1.15	1.28	1.39	1.49	1.59	1.68	1.75	1.82	1.88	1.93

Table 18. — Pulpwood values at $1.50 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.02	0.03	0.03	—	—	—	—	—	—	—	—	—
6	.03	.04	.05	0.06	—	—	—	—	—	—	—	—
7	.04	.06	.07	.08	0.10	0.11	0.12	—	—	—	—	—
8	.05	.07	.09	.11	.12	.14	.15	0.17	—	—	—	—
9	.07	.09	.12	.14	.16	.18	.20	.21	0.22	0.24	—	—
10	.08	.11	.14	.17	.20	.22	.24	.26	.28	.29	—	—
11	.10	.14	.17	.21	.24	.27	.29	.32	.34	.36	0.37	0.38
12	.12	.17	.21	.25	.29	.32	.35	.38	.41	.43	.44	.46
13	.14	.20	.25	.29	.34	.38	.42	.45	.48	.50	.52	.54
14	.17	.23	.29	.34	.39	.44	.48	.52	.56	.59	.61	.63
15	.19	.26	.33	.40	.45	.51	.56	.60	.64	.68	.70	.73
16	.22	.30	.38	.45	.52	.58	.64	.69	.73	.77	.81	.83
17	.25	.34	.43	.51	.59	.66	.73	.78	.83	.88	.91	.94
18	.28	.38	.48	.58	.66	.74	.82	.88	.94	.99	1.03	1.06
19	.32	.43	.54	.65	.74	.83	.91	.99	1.05	1.11	1.15	1.19
20	.35	.48	.60	.72	.83	.93	1.02	1.10	1.17	1.23	1.28	1.32
21	.39	.53	.67	.80	.92	1.03	1.13	1.22	1.30	1.36	1.42	1.47
22	.43	.58	.74	.88	1.01	1.13	1.24	1.34	1.43	1.50	1.57	1.62
23	.47	.64	.81	.97	1.11	1.24	1.37	1.47	1.57	1.65	1.72	1.78
24	.52	.70	.89	1.06	1.22	1.36	1.49	1.61	1.72	1.81	1.88	1.94

Table 19. — Pulpwood values at $2.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.02	0.03	0.04	0.05	0.05	—	—	—	—	—	—	—	—	—	—
6	.03	.05	.06	.07	.08	0.09	0.10	—	—	—	—	—	—	—	—
7	.05	.06	.08	.09	.11	.12	.13	0.15	0.16	—	—	—	—	—	—
8	.06	.08	.10	.12	.14	.16	.17	.19	.20	0.22	0.23	—	—	—	—
9	.08	.10	.13	.15	.18	.20	.22	.24	.26	.28	.29	0.31	0.32	—	—
10	.10	.13	.16	.19	.22	.25	.28	.30	.32	.34	.36	.38	.39	—	—
11	.12	.16	.19	.23	.27	.30	.34	.37	.39	.42	.44	.46	.48	0.50	0.51
12	.14	.19	.23	.28	.32	.36	.40	.44	.47	.50	.53	.55	.57	.59	.61
13	.16	.22	.27	.33	.38	.43	.47	.52	.55	.59	.62	.65	.68	.70	.72
14	.19	.26	.32	.38	.44	.50	.55	.60	.65	.69	.73	.76	.79	.81	.84
15	.22	.29	.37	.44	.51	.58	.64	.69	.75	.79	.84	.88	.91	.94	.96
16	.25	.34	.42	.50	.58	.66	.73	.79	.85	.91	.96	1.00	1.04	1.07	1.10
17	.29	.38	.48	.57	.66	.75	.83	.90	.97	1.03	1.08	1.14	1.18	1.22	1.25
18	.32	.43	.54	.64	.75	.84	.93	1.01	1.09	1.16	1.22	1.28	1.33	1.37	1.41
19	.36	.48	.60	.72	.83	.94	1.04	1.13	1.22	1.30	1.37	1.43	1.49	1.54	1.58
20	.40	.54	.67	.80	.93	1.05	1.16	1.26	1.36	1.44	1.52	1.59	1.66	1.71	1.76
21	.45	.59	.74	.89	1.03	1.16	1.28	1.40	1.50	1.60	1.69	1.77	1.83	1.89	1.94
22	.49	.65	.82	.98	1.14	1.28	1.42	1.54	1.66	1.76	1.86	1.95	2.02	2.09	2.14
23	.54	.72	.90	1.08	1.25	1.41	1.55	1.69	1.82	1.94	2.04	2.14	2.22	2.29	2.35
24	.59	.79	.99	1.18	1.36	1.54	1.70	1.85	1.99	2.12	2.24	2.34	2.43	2.51	2.58

Table 20. — Pulpwood values at $2.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.03	0.04	0.05	—	—	—	—	—	—	—	—	—
6	.04	.05	.07	0.08	—	—	—	—	—	—	—	—
7	.05	.07	.09	.11	0.13	0.14	0.16	—	—	—	—	—
8	.07	.10	.12	.14	.17	.19	.20	0.22	—	—	—	—
9	.09	.12	.15	.18	.21	.24	.26	.28	0.30	0.31	—	—
10	.11	.15	.19	.23	.26	.29	.32	.35	.37	.39	—	—
11	.14	.18	.23	.28	.32	.36	.39	.42	.45	.48	0.50	0.51
12	.16	.22	.28	.33	.38	.43	.47	.51	.54	.57	.59	.61
13	.19	.26	.33	.39	.45	.51	.55	.60	.64	.67	.70	.72
14	.22	.30	.38	.46	.53	.59	.65	.70	.74	.78	.81	.84
15	.26	.35	.44	.53	.61	.68	.75	.80	.86	.90	.94	.97
16	.29	.40	.50	.60	.69	.78	.85	.92	.98	1.03	1.07	1.11
17	.33	.45	.57	.68	.79	.88	.97	1.04	1.11	1.17	1.22	1.26
18	.38	.51	.64	.77	.89	.99	1.09	1.18	1.25	1.32	1.37	1.42
19	.42	.57	.72	.86	.99	1.11	1.22	1.32	1.40	1.47	1.54	1.59
20	.47	.64	.80	.96	1.10	1.24	1.36	1.46	1.56	1.64	1.71	1.77
21	.52	.71	.89	1.06	1.22	1.37	1.50	1.62	1.73	1.82	1.89	1.96
22	.57	.78	.98	1.17	1.35	1.51	1.66	1.79	1.90	2.00	2.09	2.16
23	.63	.86	1.08	1.29	1.48	1.66	1.82	1.96	2.09	2.20	2.29	2.37
24	.69	.94	1.18	1.41	1.62	1.82	1.99	2.15	2.29	2.41	2.51	2.59

Table 21. — Pulpwood values at $2.50 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.03	0.04	0.05	0.06	0.07	—	—	—	—	—	—	—	—	—	—
6	.04	.06	.07	.08	.10	0.11	0.12	—	—	—	—	—	—	—	—
7	.06	.08	.10	.12	.13	.15	.17	0.18	0.19	—	—	—	—	—	—
8	.08	.10	.13	.15	.18	.20	.22	.24	.26	0.27	0.29	—	—	—	—
9	.10	.13	.16	.19	.22	.25	.28	.30	.33	.35	.37	0.38	0.40	—	—
10	.12	.16	.20	.24	.28	.31	.34	.38	.40	.43	.45	.47	.49	—	—
11	.15	.19	.24	.29	.34	.38	.42	.46	.49	.52	.55	.58	.60	0.62	0.64
12	.17	.23	.29	.35	.40	.45	.50	.55	.59	.63	.66	.69	.72	.74	.76
13	.21	.27	.34	.41	.47	.54	.59	.64	.69	.74	.78	.81	.85	.87	.90
14	.24	.32	.40	.48	.55	.62	.69	.75	.81	.86	.91	.95	.99	1.02	1.04
15	.28	.37	.46	.55	.64	.72	.80	.87	.93	.99	1.05	1.09	1.14	1.17	1.21
16	.32	.42	.53	.63	.73	.82	.91	.99	1.07	1.13	1.20	1.25	1.30	1.34	1.38
17	.36	.48	.60	.72	.83	.93	1.03	1.12	1.21	1.29	1.36	1.42	1.47	1.52	1.56
18	.40	.54	.67	.81	.93	1.05	1.16	1.27	1.36	1.45	1.53	1.60	1.66	1.71	1.76
19	.45	.60	.75	.90	1.04	1.18	1.30	1.42	1.52	1.62	1.71	1.79	1.86	1.92	1.97
20	.50	.67	.84	1.00	1.16	1.31	1.45	1.58	1.70	1.81	1.90	1.99	2.07	2.14	2.19
21	.56	.74	.93	1.11	1.29	1.45	1.61	1.75	1.88	2.00	2.11	2.21	2.29	2.37	2.43
22	.62	.82	1.03	1.23	1.42	1.60	1.77	1.93	2.07	2.21	2.33	2.43	2.53	2.61	2.68
23	.68	.90	1.13	1.35	1.56	1.76	1.94	2.12	2.28	2.42	2.55	2.67	2.78	2.87	2.94
24	.74	.98	1.23	1.48	1.71	1.92	2.13	2.32	2.49	2.65	2.80	2.92	3.04	3.14	3.22

Table 22. — Pulpwood values at $2.50 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.03	0.05	0.06	—	—	—	—	—	—	—	—	—
6	.05	.07	.08	0.10	—	—	—	—	—	—	—	—
7	.07	.09	.12	.14	0.16	0.18	0.19	—	—	—	—	—
8	.09	.12	.15	.18	.21	.23	.26	0.28	—	—	—	—
9	.11	.15	.19	.23	.26	.30	.33	.35	0.37	0.39	—	—
10	.14	.19	.24	.29	.33	.37	.40	.44	.46	.49	—	—
11	.17	.23	.29	.35	.40	.45	.49	.53	.56	.59	0.62	0.64
12	.20	.28	.35	.42	.48	.54	.59	.63	.68	.71	.74	.76
13	.24	.33	.41	.49	.56	.63	.69	.75	.80	.84	.87	.90
14	.28	.38	.48	.57	.66	.74	.81	.87	.93	.98	1.02	1.05
15	.32	.44	.55	.66	.76	.85	.93	1.01	1.07	1.13	1.17	1.21
16	.37	.50	.63	.75	.87	.97	1.07	1.15	1.22	1.29	1.34	1.39
17	.42	.57	.72	.85	.98	1.10	1.21	1.30	1.39	1.46	1.52	1.57
18	.47	.64	.81	.96	1.11	1.24	1.36	1.47	1.56	1.65	1.71	1.77
19	.53	.72	.90	1.08	1.24	1.39	1.52	1.64	1.75	1.84	1.92	1.98
20	.59	.80	1.00	1.20	1.38	1.55	1.70	1.83	1.95	2.05	2.14	2.21
21	.65	.88	1.11	1.33	1.53	1.71	1.88	2.03	2.16	2.27	2.37	2.44
22	.72	.97	1.23	1.47	1.69	1.89	2.07	2.24	2.38	2.51	2.61	2.70
23	.79	1.07	1.35	1.61	1.85	2.07	2.28	2.46	2.61	2.75	2.87	2.96
24	.86	1.17	1.48	1.76	2.03	2.27	2.49	2.69	2.86	3.01	3.14	3.24

Table 23. — Pulpwood values at $3.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.04	0.05	0.06	0.07	0.08	—	—	—	—	—	—	—	—	—	—
6	.05	.07	.08	.10	.12	0.13	0.15	—	—	—	—	—	—	—	—
7	.07	.09	.12	.14	.16	.18	.20	0.22	0.23	—	—	—	—	—	—
8	.09	.12	.15	.18	.21	.24	.26	.29	.31	0.33	0.34	—	—	—	—
9	.12	.15	.19	.23	.27	.30	.33	.36	.39	.42	.44	0.46	0.48	—	—
10	.14	.19	.24	.29	.33	.37	.41	.45	.48	.52	.54	.57	.59	—	—
11	.18	.23	.29	.35	.40	.46	.50	.55	.59	.63	.66	.69	.72	0.74	0.76
12	.21	.28	.35	.42	.48	.54	.60	.66	.71	.75	.79	.83	.86	.89	.91
13	.25	.33	.41	.49	.57	.64	.71	.77	.83	.88	.93	.98	1.01	1.05	1.08
14	.29	.38	.48	.57	.66	.75	.83	.90	.97	1.03	1.09	1.14	1.18	1.22	1.25
15	.33	.44	.55	.66	.77	.86	.95	1.04	1.12	1.19	1.25	1.31	1.36	1.41	1.45
16	.38	.50	.63	.76	.88	.99	1.09	1.19	1.28	1.36	1.43	1.50	1.56	1.61	1.65
17	.43	.57	.72	.86	.99	1.12	1.24	1.35	1.45	1.54	1.63	1.70	1.77	1.83	1.88
18	.49	.65	.81	.97	1.12	1.26	1.40	1.52	1.63	1.74	1.83	1.92	1.99	2.06	2.11
19	.54	.72	.91	1.08	1.25	1.41	1.56	1.70	1.83	1.95	2.05	2.15	2.23	2.30	2.37
20	.60	.80	1.01	1.21	1.39	1.57	1.74	1.89	2.04	2.17	2.28	2.39	2.48	2.56	2.63
21	.67	.89	1.12	1.34	1.54	1.74	1.93	2.10	2.26	2.40	2.53	2.65	2.75	2.84	2.92
22	.74	.98	1.23	1.47	1.70	1.92	2.12	2.31	2.49	2.65	2.79	2.92	3.03	3.13	3.22
23	.81	1.08	1.35	1.62	1.87	2.11	2.33	2.54	2.73	2.91	3.06	3.21	3.33	3.44	3.53
24	.89	1.18	1.48	1.77	2.05	2.31	2.55	2.78	2.99	3.18	3.35	3.51	3.65	3.77	3.86

Table 24. — Pulpwood values at $3.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.04	0.06	0.07	—	—	—	—	—	—	—	—	—
6	.06	.08	.10	0.12	—	—	—	—	—	—	—	—
7	.08	.11	.14	.17	0.19	0.21	0.23	—	—	—	—	—
8	.11	.14	.18	.22	.25	.28	.31	0.33	—	—	—	—
9	.13	.18	.23	.28	.32	.36	.39	.42	0.45	0.47	—	—
10	.17	.23	.29	.34	.39	.44	.48	.52	.56	.59	—	—
11	.20	.28	.35	.42	.48	.54	.59	.64	.68	.71	0.74	0.77
12	.24	.33	.42	.50	.57	.64	.71	.76	.81	.85	.89	.92
13	.29	.39	.49	.59	.68	.76	.83	.90	.96	1.01	1.05	1.08
14	.33	.46	.57	.69	.79	.88	.97	1.05	1.11	1.17	1.22	1.26
15	.39	.53	.66	.79	.91	1.02	1.12	1.21	1.28	1.35	1.41	1.45
16	.44	.60	.76	.90	1.04	1.17	1.28	1.38	1.47	1.55	1.61	1.66
17	.50	.68	.86	1.03	1.18	1.32	1.45	1.56	1.67	1.75	1.83	1.89
18	.56	.77	.97	1.16	1.33	1.49	1.63	1.76	1.88	1.98	2.06	2.12
19	.63	.86	1.08	1.29	1.49	1.67	1.83	1.97	2.10	2.21	2.30	2.38
20	.70	.96	1.21	1.44	1.66	1.86	2.04	2.20	2.34	2.46	2.56	2.65
21	.78	1.06	1.34	1.60	1.84	2.06	2.26	2.43	2.59	2.73	2.84	2.93
22	.86	1.17	1.47	1.76	2.02	2.27	2.49	2.68	2.86	3.01	3.13	3.24
23	.94	1.28	1.62	1.93	2.22	2.49	2.73	2.95	3.14	3.30	3.44	3.55
24	1.03	1.40	1.77	2.11	2.43	2.72	2.99	3.23	3.43	3.61	3.77	3.89

Table 25. — Pulpwood values at $4.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.05	0.06	0.08	0.09	0.11	—	—	—	—	—	—	—	—	—	—
6	.07	.09	.11	.14	.16	0.18	0.19	—	—	—	—	—	—	—	—
7	.09	.12	.15	.18	.21	.24	.27	0.29	0.31	—	—	—	—	—	—
8	.12	.16	.20	.24	.28	.32	.35	.38	.41	0.44	0.46	—	—	—	—
9	.15	.21	.26	.31	.36	.40	.44	.48	.52	.55	.58	0.61	0.64	—	—
10	.19	.26	.32	.38	.44	.50	.55	.60	.65	.69	.73	.76	.79	—	—
11	.23	.31	.39	.47	.54	.61	.67	.73	.79	.84	.88	.92	.96	0.99	1.02
12	.28	.37	.47	.56	.64	.73	.80	.87	.94	1.00	1.05	1.10	1.15	1.18	1.22
13	.33	.44	.55	.66	.76	.86	.95	1.03	1.11	1.18	1.24	1.30	1.35	1.40	1.43
14	.38	.51	.64	.77	.88	1.00	1.10	1.20	1.29	1.38	1.45	1.52	1.58	1.63	1.67
15	.44	.59	.74	.88	1.02	1.15	1.27	1.39	1.49	1.59	1.67	1.75	1.82	1.88	1.93
16	.51	.67	.84	1.01	1.17	1.32	1.46	1.59	1.70	1.81	1.91	2.00	2.08	2.15	2.20
17	.57	.76	.96	1.15	1.32	1.49	1.65	1.80	1.93	2.06	2.17	2.27	2.36	2.44	2.50
18	.65	.86	1.08	1.29	1.49	1.68	1.86	2.03	2.18	2.32	2.44	2.56	2.66	2.74	2.82
19	.72	.96	1.21	1.44	1.67	1.88	2.08	2.27	2.44	2.59	2.74	2.86	2.97	3.07	3.15
20	.81	1.07	1.34	1.61	1.86	2.10	2.32	2.52	2.71	2.89	3.05	3.19	3.31	3.42	3.51
21	.89	1.19	1.49	1.78	2.06	2.32	2.57	2.80	3.01	3.20	3.37	3.53	3.67	3.79	3.89
22	.99	1.31	1.64	1.96	2.27	2.56	2.83	3.08	3.32	3.53	3.72	3.89	4.05	4.18	4.29
23	1.08	1.44	1.80	2.16	2.49	2.81	3.11	3.39	3.64	3.88	4.09	4.28	4.44	4.59	4.71
24	1.18	1.57	1.97	2.36	2.73	3.08	3.40	3.70	3.98	4.24	4.47	4.68	4.86	5.02	5.15

Table 26. — Pulpwood values at $4.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.05	0.07	0.09	—	—	—	—	—	—	—	—	—
6	.08	.11	.14	0.16	—	—	—	—	—	—	—	—
7	.11	.15	.18	.22	0.25	0.28	0.31	—	—	—	—	—
8	.14	.19	.24	.29	.33	.37	.41	0.44	—	—	—	—
9	.18	.24	.31	.37	.42	.47	.52	.56	0.60	0.63	—	—
10	.22	.30	.38	.46	.53	.59	.65	.70	.74	.78	—	—
11	.27	.37	.47	.56	.64	.72	.79	.85	.90	.95	0.99	1.02
12	.32	.44	.56	.66	.77	.83	.94	1.01	1.08	1.14	1.18	1.22
13	.38	.52	.66	.78	.90	1.01	1.11	1.20	1.27	1.34	1.40	1.44
14	.45	.61	.77	.91	1.05	1.18	1.29	1.39	1.48	1.56	1.63	1.68
15	.51	.70	.88	1.05	1.21	1.36	1.49	1.61	1.71	1.80	1.88	1.94
16	.59	.80	1.01	1.21	1.39	1.55	1.70	1.84	1.96	2.06	2.15	2.22
17	.67	.91	1.15	1.37	1.57	1.76	1.93	2.09	2.22	2.34	2.44	2.51
18	.75	1.02	1.29	1.54	1.77	1.99	2.18	2.35	2.50	2.63	2.74	2.83
19	.84	1.15	1.44	1.72	1.98	2.22	2.44	2.63	2.80	2.95	3.07	3.17
20	.94	1.28	1.61	1.92	2.21	2.47	2.71	2.93	3.12	3.28	3.42	3.53
21	1.04	1.41	1.78	2.13	2.45	2.74	3.01	3.25	3.46	3.64	3.79	3.91
22	1.14	1.56	1.96	2.35	2.70	3.02	3.32	3.58	3.81	4.01	4.18	4.31
23	1.26	1.71	2.16	2.58	2.96	3.32	3.64	3.93	4.18	4.40	4.59	4.74
24	1.38	1.87	2.36	2.82	3.24	3.63	3.98	4.30	4.58	4.82	5.02	5.18

Table 27. — Pulpwood values at $5.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.06	0.08	0.10	0.12	0.13	—	—	—	—	—	—	—	—	—	—
6	.08	.11	.14	.17	.20	0.22	0.24	—	—	—	—	—	—	—	—
7	.12	.15	.19	.23	.27	.30	.33	0.36	0.39	—	—	—	—	—	—
8	.15	.20	.25	.30	.35	.40	.44	.48	.51	0.54	0.57	—	—	—	—
9	.19	.26	.32	.39	.45	.50	.56	.61	.65	.69	.73	0.76	0.79	—	—
10	.24	.32	.40	.48	.55	.62	.69	.75	.81	.86	.91	.95	.99	—	—
11	.29	.39	.49	.58	.67	.76	.84	.91	.98	1.05	1.10	1.15	1.20	1.24	1.27
12	.35	.46	.58	.70	.80	.91	1.00	1.09	1.18	1.25	1.32	1.38	1.43	1.48	1.52
13	.41	.55	.69	.82	.95	1.07	1.18	1.29	1.39	1.47	1.56	1.63	1.69	1.75	1.79
14	.48	.64	.80	.96	1.11	1.25	1.38	1.50	1.62	1.72	1.81	1.90	1.97	2.03	2.09
15	.55	.74	.92	1.10	1.28	1.44	1.59	1.73	1.86	1.98	2.09	2.19	2.27	2.35	2.41
16	.63	.84	1.05	1.26	1.46	1.65	1.82	1.98	2.13	2.27	2.39	2.50	2.60	2.68	2.76
17	.72	.95	1.20	1.43	1.66	1.87	2.06	2.25	2.42	2.57	2.71	2.84	2.95	3.04	3.13
18	.81	1.08	1.35	1.61	1.86	2.10	2.33	2.53	2.72	2.90	3.06	3.20	3.32	3.43	3.52
19	.91	1.20	1.51	1.81	2.09	2.35	2.60	2.83	3.05	3.24	3.42	3.58	3.72	3.84	3.94
20	1.01	1.34	1.68	2.01	2.32	2.62	2.90	3.16	3.39	3.61	3.81	3.98	4.14	4.27	4.39
21	1.12	1.48	1.86	2.23	2.57	2.90	3.21	3.50	3.76	4.00	4.22	4.41	4.59	4.74	4.86
22	1.23	1.64	2.05	2.45	2.84	3.20	3.54	3.85	4.15	4.41	4.65	4.87	5.06	5.22	5.36
23	1.35	1.80	2.25	2.70	3.12	3.52	3.89	4.23	4.55	4.84	5.11	5.34	5.55	5.73	5.89
24	1.48	1.97	2.47	2.95	3.41	3.85	4.26	4.63	4.98	5.30	5.59	5.85	6.08	6.28	6.44

Table 28. — Pulpwood values at $5.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.07	0.09	0.12	—	—	—	—	—	—	—	—	—
6	.10	.13	.17	0.20	—	—	—	—	—	—	—	—
7	.13	.18	.23	.28	0.32	0.36	0.39	—	—	—	—	—
8	.18	.24	.30	.36	.42	.47	.51	0.55	—	—	—	—
9	.22	.31	.39	.46	.53	.59	.65	.70	0.75	0.79	—	—
10	.28	.38	.48	.57	.66	.74	.81	.87	.93	.98	—	—
11	.34	.46	.58	.69	.80	.90	.98	1.06	1.13	1.19	1.24	1.28
12	.41	.55	.70	.83	.96	1.07	1.18	1.27	1.35	1.42	1.48	1.53
13	.48	.65	.82	.98	1.13	1.26	1.39	1.50	1.59	1.68	1.75	1.80
14	.56	.76	.96	1.14	1.31	1.47	1.62	1.74	1.86	1.95	2.03	2.10
15	.64	.88	1.10	1.32	1.52	1.70	1.86	2.01	2.14	2.25	2.35	2.42
16	.74	1.00	1.26	1.51	1.73	1.94	2.13	2.30	2.45	2.58	2.68	2.77
17	.83	1.14	1.43	1.71	1.97	2.20	2.42	2.61	2.78	2.92	3.04	3.14
18	.94	1.28	1.61	1.93	2.22	2.48	2.72	2.94	3.13	3.29	3.43	3.54
19	1.05	1.43	1.81	2.16	2.48	2.78	3.05	3.29	3.50	3.69	3.84	3.96
20	1.17	1.60	2.01	2.40	2.76	3.09	3.39	3.66	3.90	4.10	4.27	4.41
21	1.30	1.77	2.23	2.66	3.06	3.43	3.76	4.06	4.32	4.55	4.74	4.89
22	1.43	1.95	2.45	2.93	3.37	3.78	4.15	4.47	4.76	5.01	5.22	5.39
23	1.57	2.14	2.70	3.22	3.70	4.15	4.55	4.91	5.23	5.50	5.73	5.92
24	1.72	2.34	2.95	3.52	4.06	4.54	4.98	5.38	5.72	6.02	6.28	6.48

Table 29. — Pulpwood values at $7.50 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.09	0.12	0.15	0.17	0.20	—	—	—	—	—	—	—	—	—	—
6	.13	.17	.21	.25	.29	0.33	0.37	—	—	—	—	—	—	—	—
7	.17	.23	.29	.35	.40	.45	.50	0.54	0.58	—	—	—	—	—	—
8	.23	.30	.38	.45	.53	.59	.66	.71	.77	0.82	0.86	—	—	—	—
9	.29	.39	.48	.58	.67	.75	.83	.91	.98	1.04	1.10	1.15	1.19	—	—
10	.36	.48	.60	.72	.83	.94	1.03	1.13	1.21	1.29	1.36	1.42	1.48	—	—
11	.44	.58	.73	.87	1.01	1.14	1.26	1.37	1.47	1.57	1.65	1.73	1.80	1.86	1.91
12	.52	.70	.87	1.04	1.21	1.36	1.51	1.64	1.76	1.88	1.98	2.07	2.15	2.22	2.28
13	.62	.82	1.03	1.23	1.42	1.61	1.78	1.93	2.08	2.21	2.33	2.44	2.54	2.62	2.69
14	.72	.96	1.20	1.43	1.66	1.87	2.07	2.25	2.42	2.58	2.72	2.84	2.96	3.05	3.13
15	.83	1.10	1.38	1.66	1.91	2.16	2.39	2.60	2.80	2.97	3.14	3.28	3.41	3.52	3.62
16	.95	1.26	1.58	1.89	2.19	2.47	2.73	2.97	3.20	3.40	3.59	3.75	3.90	4.03	4.13
17	1.08	1.43	1.79	2.15	2.48	2.80	3.10	3.37	3.63	3.86	4.07	4.26	4.42	4.57	4.69
18	1.21	1.61	2.02	2.42	2.80	3.15	3.49	3.80	4.08	4.35	4.58	4.79	4.98	5.14	5.28
19	1.36	1.81	2.26	2.71	3.13	3.53	3.90	4.25	4.57	4.87	5.13	5.37	5.58	5.76	5.91
20	1.51	2.01	2.52	3.01	3.49	3.93	4.35	4.73	5.09	5.42	5.71	5.98	6.21	6.41	6.58
21	1.67	2.23	2.79	3.34	3.86	4.35	4.82	5.24	5.64	6.00	6.33	6.62	6.88	7.10	7.29
22	1.85	2.46	3.08	3.68	4.26	4.80	5.31	5.78	6.22	6.62	6.98	7.30	7.59	7.83	8.04
23	2.03	2.70	3.38	4.04	4.68	5.27	5.83	6.35	6.83	7.27	7.66	8.02	8.33	8.60	8.83
24	2.22	2.95	3.70	4.43	5.12	5.77	6.38	6.95	7.47	7.95	8.39	8.77	9.11	9.41	9.66

Table 30. — Pulpwood values at $7.50 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.10	0.14	0.17	—	—	—	—	—	—	—	—	—
6	.15	.20	.25	0.30	—	—	—	—	—	—	—	—
7	.20	.28	.35	.41	0.48	0.53	0.58	—	—	—	—	—
8	.27	.36	.45	.54	.62	.70	.77	0.83	—	—	—	—
9	.34	.46	.58	.69	.79	.89	.98	1.05	1.12	1.18	—	—
10	.42	.57	.72	.86	.99	1.10	1.21	1.31	1.39	1.47	—	—
11	.51	.69	.87	1.04	1.20	1.34	1.47	1.59	1.69	1.78	1.86	1.92
12	.61	.83	1.04	1.25	1.43	1.61	1.76	1.90	2.03	2.13	2.22	2.29
13	.72	.98	1.23	1.47	1.69	1.89	2.08	2.24	2.39	2.51	2.62	2.70
14	.84	1.14	1.43	1.71	1.97	2.21	2.42	2.61	2.78	2.93	3.05	3.15
15	.96	1.31	1.66	1.98	2.27	2.55	2.80	3.02	3.21	3.38	3.52	3.64
16	1.10	1.50	1.89	2.26	2.60	2.91	3.20	3.45	3.67	3.86	4.03	4.16
17	1.25	1.70	2.15	2.56	2.95	3.30	3.63	3.91	4.16	4.38	4.57	4.72
18	1.41	1.92	2.42	2.89	3.32	3.72	4.08	4.41	4.69	4.94	5.14	5.31
19	1.58	2.15	2.71	3.23	3.72	4.17	4.57	4.93	5.25	5.53	5.76	5.95
20	1.76	2.39	3.01	3.60	4.14	4.64	5.09	5.49	5.85	6.15	6.41	6.62
21	1.95	2.65	3.34	3.99	4.59	5.14	5.64	6.09	6.48	6.82	7.10	7.33
22	2.15	2.92	3.68	4.40	5.06	5.67	6.22	6.71	7.14	7.52	7.83	8.09
23	2.36	3.21	4.04	4.83	5.56	6.22	6.83	7.37	7.84	8.26	8.60	8.88
24	2.58	3.51	4.43	5.28	6.08	6.81	7.47	8.06	8.58	9.03	9.41	9.72

Table 31. — Pulpwood values at $10.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.12	0.16	0.19	0.23	0.27	—	—	—	—	—	—	—	—	—	—
6	.17	.23	.28	.34	.39	0.44	0.49	—	—	—	—	—	—	—	—
7	.23	.31	.39	.46	.53	.60	.67	0.73	0.78	—	—	—	—	—	—
8	.30	.40	.51	.61	.70	.79	.87	.95	1.02	1.09	1.15	—	—	—	—
9	.39	.51	.64	.77	.89	1.01	1.11	1.21	1.30	1.39	1.46	1.53	1.59	—	—
10	.48	.64	.80	.96	1.11	1.25	1.38	1.50	1.62	1.72	1.81	1.90	1.97	—	—
11	.58	.78	.97	1.16	1.35	1.52	1.68	1.83	1.97	2.09	2.21	2.31	2.40	2.48	2.54
12	.70	.93	1.16	1.39	1.61	1.81	2.01	2.19	2.35	2.50	2.64	2.76	2.87	2.96	3.04
13	.82	1.09	1.37	1.64	1.90	2.14	2.37	2.58	2.77	2.95	3.11	3.25	3.38	3.49	3.59
14	.96	1.28	1.60	1.91	2.21	2.49	2.76	3.00	3.23	3.44	3.63	3.79	3.94	4.07	4.18
15	1.11	1.47	1.84	2.21	2.55	2.88	3.18	3.47	3.73	3.97	4.18	4.38	4.55	4.69	4.82
16	1.27	1.68	2.11	2.52	2.92	3.29	3.64	3.96	4.26	4.53	4.78	5.00	5.20	5.37	5.51
17	1.44	1.91	2.39	2.86	3.31	3.73	4.13	4.50	4.83	5.14	5.42	5.68	5.90	6.09	6.25
18	1.62	2.15	2.70	3.22	3.73	4.20	4.65	5.06	5.45	5.79	6.11	6.39	6.64	6.86	7.04
19	1.81	2.41	3.02	3.61	4.17	4.71	5.21	5.67	6.10	6.49	6.84	7.16	7.44	7.68	7.88
20	2.02	2.68	3.36	4.02	4.65	5.24	5.80	6.31	6.79	7.22	7.62	7.97	8.28	8.55	8.78
21	2.23	2.97	3.72	4.45	5.15	5.81	6.42	6.99	7.52	8.00	8.44	8.83	9.17	9.47	9.72
22	2.46	3.27	4.10	4.91	5.68	6.40	7.08	7.71	8.29	8.82	9.30	9.73	10.11	10.44	10.72
23	2.79	3.60	4.51	5.39	6.23	7.03	7.77	8.47	9.10	9.69	10.22	10.69	11.11	11.47	11.77
24	2.96	3.93	4.93	5.90	6.82	7.69	8.51	9.26	9.96	10.60	11.18	11.69	12.15	12.55	12.88

Table 32. — Pulpwood values at $10.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.14	0.19	0.23	—	—	—	—	—	—	—	—	—
6	.20	.27	.34	0.40	—	—	—	—	—	—	—	—
7	.27	.37	.46	.55	0.63	0.71	0.78	—	—	—	—	—
8	.35	.48	.61	.72	.83	.93	1.02	1.10	—	—	—	—
9	.45	.61	.77	.92	1.06	1.19	1.30	1.41	1.50	1.57	—	—
10	.56	.76	.96	1.14	1.32	1.47	1.62	1.74	1.86	1.95	—	—
11	.68	.92	1.16	1.39	1.60	1.79	1.97	2.12	2.26	2.38	2.48	2.56
12	.81	1.11	1.39	1.66	1.91	2.14	2.35	2.54	2.70	2.84	2.96	3.06
13	.96	1.30	1.64	1.96	2.26	2.53	2.77	2.99	3.18	3.35	3.49	3.61
14	1.12	1.52	1.91	2.28	2.63	2.94	3.23	3.49	3.71	3.91	4.07	4.20
15	1.29	1.75	2.21	2.64	3.03	3.40	3.73	4.02	4.28	4.51	4.69	4.85
16	1.47	2.00	2.52	3.01	3.47	3.88	4.26	4.60	4.90	5.15	5.37	5.54
17	1.67	2.27	2.86	3.42	3.93	4.41	4.83	5.22	5.55	5.84	6.09	6.29
18	1.88	2.56	3.22	3.85	4.43	4.96	5.45	5.88	6.26	6.58	6.86	7.08
19	2.10	2.87	3.61	4.31	4.96	5.56	6.10	6.58	7.00	7.37	7.68	7.93
20	2.34	3.19	4.02	4.80	5.52	6.19	6.79	7.32	7.80	8.21	8.55	8.83
21	2.59	3.54	4.45	5.32	6.12	6.85	7.52	8.11	8.64	9.09	9.47	9.78
22	2.86	3.90	4.91	5.86	6.75	7.56	8.29	8.95	9.52	10.02	10.44	10.78
23	3.14	4.28	5.39	6.44	7.41	8.30	9.10	9.82	10.46	11.01	11.47	11.84
24	3.44	4.68	5.90	7.04	8.11	9.08	9.96	10.75	11.44	12.04	12.55	12.96

Table 33. — Pulpwood values at $15.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.18	0.23	0.29	0.35	0.40	—	—	—	—	—	—	—	—	—	—
6	.25	.34	.42	.51	.59	0.66	0.73	—	—	—	—	—	—	—	—
7	.35	.46	.58	.69	.80	.90	1.00	1.09	1.17	—	—	—	—	—	—
8	.46	.61	.76	.91	1.05	1.19	1.31	1.43	1.54	1.63	1.72	—	—	—	—
9	.58	.77	.97	1.16	1.34	1.51	1.67	1.82	1.95	2.08	2.19	2.29	2.38	—	—
10	.72	.96	1.20	1.44	1.66	1.87	2.07	2.25	2.42	2.58	2.72	2.85	2.96	—	—
11	.88	1.16	1.46	1.75	2.02	2.28	2.52	2.74	2.95	3.14	3.31	3.46	3.60	3.71	3.81
12	1.05	1.39	1.75	2.09	2.41	2.72	3.01	3.28	3.53	3.75	3.96	4.14	4.30	4.44	4.56
13	1.24	1.64	2.06	2.46	2.85	3.21	3.55	3.87	4.16	4.42	4.67	4.88	5.07	5.24	5.38
14	1.44	1.91	2.40	2.87	3.22	3.74	4.14	4.51	4.85	5.16	5.44	5.69	5.91	6.10	6.27
15	1.66	2.21	2.77	3.31	3.83	4.32	4.77	5.20	5.59	5.95	6.27	6.56	6.82	7.04	7.23
16	1.90	2.52	3.16	3.79	4.38	4.94	5.46	5.94	6.39	6.80	7.17	7.50	7.80	8.05	8.27
17	2.15	2.86	3.59	4.29	4.97	5.60	6.19	6.74	7.25	7.72	8.14	8.51	8.85	9.13	9.38
18	2.43	3.23	4.04	4.84	5.59	6.31	6.98	7.60	8.17	8.69	9.17	9.59	9.96	10.29	10.56
19	2.72	3.61	4.53	5.42	6.26	7.06	7.81	8.50	9.14	9.73	10.26	10.74	11.16	11.52	11.83
20	3.02	4.02	5.04	6.03	6.97	7.86	8.69	9.47	10.18	10.83	11.42	11.95	12.42	12.82	13.17
21	3.35	4.45	5.58	6.68	7.72	8.71	9.63	10.49	11.28	12.00	12.65	13.24	13.76	14.21	14.59
22	3.69	4.91	6.16	7.36	8.52	9.60	10.62	11.56	12.44	13.23	13.95	14.60	15.17	15.67	16.08
23	4.06	5.39	6.76	8.09	9.35	10.55	11.66	12.70	13.66	14.53	15.32	16.03	16.66	17.20	17.66
24	4.44	5.90	7.40	8.85	10.23	11.54	12.77	13.89	14.94	15.90	16.77	17.54	18.23	18.83	19.32

Table 34. — Pulpwood values at $15.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.20	0.28	0.35	—	—	—	—	—	—	—	—	—
6	.30	.40	.51	0.60	—	—	—	—	—	—	—	—
7	.40	.55	.69	.83	0.95	1.07	1.17	—	—	—	—	—
8	.53	.72	.91	1.09	1.25	1.40	1.54	1.66	—	—	—	—
9	.67	.92	1.16	1.38	1.59	1.78	1.95	2.11	2.24	2.36	—	—
10	.84	1.14	1.44	1.71	1.97	2.21	2.42	2.62	2.78	2.93	—	—
11	1.02	1.39	1.75	2.08	2.40	2.69	2.95	3.18	3.39	3.56	3.71	3.83
12	1.22	1.66	2.09	2.49	2.87	3.21	3.53	3.80	4.05	4.26	4.44	4.59
13	1.44	1.96	2.46	2.94	3.38	3.79	4.16	4.49	4.78	5.03	5.24	5.41
14	1.67	2.28	2.87	3.43	3.94	4.42	4.85	5.23	5.57	5.86	6.10	6.30
15	1.93	2.63	3.31	3.95	4.55	5.10	5.59	6.03	6.42	6.76	7.04	7.27
16	2.21	3.01	3.79	4.52	5.20	5.83	6.39	6.90	7.34	7.73	8.05	8.31
17	2.50	3.41	4.29	5.13	5.90	6.61	7.25	7.82	8.33	8.77	9.13	9.43
18	2.82	3.84	4.84	5.78	6.65	7.44	8.17	8.81	9.38	9.88	10.29	10.62
19	3.16	4.30	5.42	6.47	7.44	8.34	9.14	9.87	10.51	11.06	11.52	11.89
20	3.51	4.79	6.03	7.20	8.29	9.28	10.18	10.99	11.70	12.31	12.82	13.24
21	3.89	5.30	6.68	7.98	9.18	10.28	11.28	12.17	12.96	13.64	14.21	14.67
22	4.29	5.85	7.36	8.79	10.12	11.34	12.44	13.42	14.29	15.04	15.67	16.18
23	4.71	6.42	8.09	9.66	11.11	12.45	13.66	14.74	15.69	16.51	17.20	17.76
24	5.16	7.02	8.85	10.56	12.17	13.62	14.94	16.13	17.16	18.06	18.83	19.44

Table 35. — Pulpwood values at $20.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.24	0.32	0.38	0.46	0.54	—	—	—	—	—	—	—	—	—	—
6	.34	.46	.56	.68	.78	0.88	0.98	—	—	—	—	—	—	—	—
7	.46	.62	.78	.92	1.06	1.20	1.34	1.46	1.56	—	—	—	—	—	—
8	.60	.80	1.02	1.22	1.40	1.58	1.74	1.90	2.04	2.18	2.30	—	—	—	—
9	.78	1.02	1.28	1.54	1.78	2.02	2.22	2.42	2.60	2.78	2.92	3.06	3.18	—	—
10	.96	1.28	1.60	1.92	2.22	2.50	2.76	3.00	3.24	3.44	3.62	3.80	3.94	—	—
11	1.16	1.56	1.94	2.32	2.70	3.04	3.36	3.66	3.94	4.18	4.42	4.62	4.80	4.96	5.08
12	1.40	1.86	2.32	2.78	3.22	3.62	4.02	4.38	4.70	5.00	5.28	5.52	5.74	5.92	6.08
13	1.64	2.18	2.74	3.28	3.80	4.28	4.74	5.16	5.54	5.90	6.22	6.50	6.76	6.98	7.18
14	1.92	2.56	3.20	3.82	4.42	4.98	5.52	6.00	6.46	6.88	7.26	7.58	7.88	8.14	8.36
15	2.22	2.94	3.68	4.42	5.10	5.76	6.36	6.94	7.46	7.94	8.36	8.76	9.10	9.38	9.64
16	2.54	3.36	4.22	5.04	5.84	6.58	7.28	7.92	8.52	9.06	9.56	10.00	10.40	10.74	11.02
17	2.88	3.82	4.78	5.72	6.62	7.46	8.26	9.00	9.66	10.28	10.84	11.36	11.84	12.18	12.50
18	3.24	4.30	5.40	6.44	7.46	8.40	9.30	10.12	10.90	11.58	12.22	12.78	13.28	13.72	14.08
19	3.62	4.82	6.04	7.22	8.34	9.42	10.42	11.34	12.20	12.98	13.68	14.32	14.88	15.36	15.76
20	4.04	5.36	6.72	8.04	9.30	10.48	11.60	12.62	13.58	14.44	15.24	15.94	16.56	17.10	17.56
21	4.46	5.94	7.44	8.90	10.30	11.62	12.84	13.98	15.04	16.00	16.88	17.66	18.34	18.94	19.44
22	4.92	6.54	8.20	9.82	11.36	12.80	14.16	15.42	16.58	17.64	18.60	19.46	20.22	20.88	21.44
23	5.40	7.20	9.02	10.78	12.46	14.06	15.54	16.94	18.20	19.38	20.44	21.38	22.22	22.94	23.54
24	5.92	7.86	9.86	11.80	13.64	15.38	17.02	18.52	19.92	21.20	22.36	23.38	24.30	25.10	25.76

Table 36. — Pulpwood values at $20.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.28	0.38	0.46	—	—	—	—	—	—	—	—	—
6	.40	.54	.68	0.80	—	—	—	—	—	—	—	—
7	.54	.74	.92	1.10	1.26	1.42	1.56	—	—	—	—	—
8	.70	.96	1.22	1.44	1.66	1.86	2.04	2.20	—	—	—	—
9	.90	1.22	1.54	1.84	2.12	2.38	2.60	2.82	3.00	3.14	—	—
10	1.12	1.52	1.92	2.28	2.64	2.94	3.24	3.48	3.72	3.90	—	—
11	1.33	1.84	2.32	2.78	3.20	3.58	3.94	4.24	4.52	4.76	4.96	5.12
12	1.62	2.22	2.78	3.32	3.82	4.28	4.70	5.08	5.40	5.68	5.92	6.12
13	1.92	2.60	3.28	3.92	4.52	5.06	5.54	5.98	6.36	6.70	6.98	7.22
14	2.24	3.04	3.82	4.56	5.26	5.88	6.46	6.98	7.42	7.82	8.14	8.40
15	2.58	3.50	4.42	5.28	6.06	6.80	7.46	8.04	8.56	9.02	9.38	9.70
16	2.94	4.00	5.04	6.02	6.94	7.76	8.52	9.20	9.80	10.30	10.74	11.08
17	3.34	4.54	5.72	6.84	7.86	8.82	9.66	10.44	11.10	11.68	12.18	12.58
18	3.76	5.12	6.44	7.70	8.86	9.92	10.90	11.76	12.52	13.16	13.72	14.16
19	4.20	5.74	7.22	8.62	9.92	11.12	12.20	13.16	14.00	14.74	15.36	15.86
20	4.68	6.38	8.04	9.60	11.04	12.38	13.58	14.64	15.60	16.42	17.10	17.66
21	5.18	7.08	8.90	10.64	12.24	13.70	15.04	16.22	17.28	18.18	18.94	19.56
22	5.72	7.80	9.82	11.72	13.50	15.12	16.58	17.90	19.04	20.04	20.88	21.56
23	6.28	8.56	10.78	12.88	14.82	16.60	18.20	19.64	20.92	22.02	22.94	23.68
24	6.88	9.36	11.80	14.08	16.22	18.16	19.92	21.50	22.88	24.08	25.10	25.92

Table 37. — Pulpwood values at $25.00 per cord

Dbh (inches)	Merchantable height in feet														
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	0.30	0.40	0.48	0.58	0.68	—	—	—	—	—	—	—	—	—	—
6	.43	.58	.70	.85	.98	1.10	1.23	—	—	—	—	—	—	—	—
7	.58	.78	.98	1.15	1.33	1.50	1.68	1.83	1.95	—	—	—	—	—	—
8	.75	1.00	1.28	1.53	1.75	1.98	2.18	2.38	2.55	2.73	2.88	—	—	—	—
9	.98	1.28	1.60	1.93	2.23	2.53	2.78	3.03	3.25	3.48	3.65	3.83	3.98	—	—
10	1.20	1.60	2.00	2.40	2.78	3.13	3.45	3.75	4.05	4.30	4.53	4.75	4.93	—	—
11	1.45	1.95	2.43	2.90	3.38	3.80	4.20	4.58	4.93	5.23	5.53	5.78	6.00	6.20	6.35
12	1.75	2.33	2.90	3.48	4.03	4.53	5.03	5.48	5.88	6.25	6.60	6.90	7.18	7.40	7.60
13	2.05	2.73	3.43	4.10	4.75	5.35	5.93	6.45	6.93	7.38	7.78	8.13	8.45	8.73	8.98
14	2.40	3.20	4.00	4.78	5.53	6.23	6.90	7.50	8.08	8.60	9.08	9.48	9.85	10.18	10.45
15	2.78	3.68	4.60	5.53	6.38	7.20	7.95	8.68	9.33	9.93	10.45	10.95	11.38	11.73	12.05
16	3.18	4.20	5.28	6.30	7.30	8.23	9.10	9.90	10.65	11.33	11.95	12.50	13.00	13.43	13.78
17	3.60	4.78	5.98	7.15	8.28	9.33	10.33	11.25	12.08	12.85	13.55	14.20	14.75	15.23	15.63
18	4.05	5.38	6.75	8.05	9.33	10.50	11.63	12.65	13.63	14.48	15.28	15.98	16.60	17.15	17.60
19	4.53	6.03	7.55	9.03	10.43	11.78	13.03	14.18	15.25	16.23	17.10	17.90	18.60	19.20	19.70
20	5.05	6.70	8.40	10.05	11.63	13.10	14.50	15.78	16.98	18.05	19.05	19.93	20.70	21.38	21.95
21	5.58	7.43	9.30	11.13	12.88	14.53	16.05	17.48	18.80	20.00	21.10	22.08	22.93	23.68	24.30
22	6.15	8.18	10.25	12.28	14.20	16.00	17.70	19.28	20.73	22.05	23.25	24.33	25.28	26.10	26.80
23	6.75	9.00	11.28	13.48	15.58	17.58	19.43	21.18	22.75	24.23	25.55	26.73	27.78	28.68	29.43
24	7.40	9.83	12.33	14.75	17.05	19.23	21.28	23.15	24.90	26.50	27.95	29.23	30.38	31.38	32.20

Table 38. — Pulpwood values at $25.00 per cord

Dbh (inches)	Merchantable height in feet											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.35	0.48	0.58	—	—	—	—	—	—	—	—	—
6	.50	.68	.85	1.00	—	—	—	—	—	—	—	—
7	.68	.93	1.15	1.38	1.58	1.78	1.95	—	—	—	—	—
8	.88	1.20	1.53	1.80	2.08	2.33	2.55	2.75	—	—	—	—
9	1.13	1.53	1.93	2.30	2.65	2.98	3.25	3.53	3.75	3.93	—	—
10	1.40	1.90	2.40	2.85	3.30	3.68	4.05	4.35	4.65	4.88	—	—
11	1.70	2.30	2.90	3.48	4.00	4.48	4.93	5.30	5.65	5.95	6.20	6.40
12	2.03	2.78	3.48	4.15	4.78	5.35	5.88	6.35	6.75	7.10	7.40	7.65
13	2.40	3.25	4.10	4.90	5.65	6.33	6.93	7.48	7.95	8.38	8.73	9.03
14	2.80	3.80	4.78	5.70	6.58	7.35	8.08	8.73	9.28	9.78	10.18	10.50
15	3.23	4.38	5.53	6.60	7.58	8.50	9.33	10.05	10.70	11.28	11.73	12.13
16	3.68	5.00	6.30	7.53	8.68	9.70	10.65	11.50	12.25	12.88	13.43	13.85
17	4.18	5.68	7.15	8.55	9.83	11.03	12.08	13.05	13.88	14.60	15.23	15.73
18	4.70	6.40	8.05	9.63	11.08	12.40	13.63	14.70	15.65	16.45	17.15	17.70
19	5.25	7.18	9.03	10.78	12.40	13.90	15.25	16.45	17.50	18.43	19.20	19.83
20	5.85	7.98	10.05	12.00	13.80	15.48	16.98	18.30	19.50	20.53	21.38	22.08
21	6.48	8.85	11.13	13.30	15.30	17.13	18.80	20.28	21.60	22.73	23.68	24.45
22	7.15	9.75	12.28	14.65	16.88	18.90	20.73	22.38	23.80	25.05	26.10	26.95
23	7.85	10.70	13.48	16.10	18.53	20.75	22.75	24.55	26.15	27.53	28.68	29.60
24	8.60	11.70	14.75	17.60	20.28	22.70	24.90	26.88	28.60	30.10	31.38	32.40

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DeBald, Paul S., and Joseph J. Mendel.
1976. **Composite volume and value tables for hardwood pulpwood. (SETs: Stand Evaluation Tools. 3.)** Northeast. Forest Exp. Stn., Upper Darby, Pa.
43 p. (USDA For. Serv. Res. Pap. NE-338)

Presents 38 composite volume and value tables for hardwood pulpwood, with examples of how they can be applied to individual standing trees or to the pulpwood portions of sawtimber trees.

652.3:524.3:861.0- -176.1

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MANUSCRIPT RECEIVED FOR PUBLICATION 27 MAY 1975

Suitability of the Line Intersect Method for Sampling Hardwood Logging Residues

Abstract

The line intersect method of sampling logging residues was tested in Appalachian hardwoods and was found to provide unbiased estimates of the volume of residue in cubic feet per acre. Thirty-two chains of sample line were established on each of sixteen 1-acre plots on cutover areas in a variety of conditions. Estimates from these samples were then compared to actual volumes obtained from a 100 percent cruise of each plot. No consistent bias was found; and, when species, slope, cutting method, road influence, and piece length were examined, their effects were found to be nonsignificant.

From the average variance found with the line intersect method, a table of recommended sample sizes for several levels of precision was prepared. From the study, it was also learned that sampling time is directly related to residue volume per acre and type of cut; however, the relation is not as strong with the line intersect method as with fixed-area plots.

Introduction

ALTHOUGH LOGGING residues have always been a byproduct of timber harvesting, it has only been during the past few years that attention has really been focused on their utilization. In many parts of the country, logging slash has always posed problems by interfering with site preparation and increasing the danger of fire by fuel accumulation. However, the era of environmentalism (with greater concern for aesthetics, air and water quality, and additional energy sources) and the need for more raw materials in the paper, board, and sawn product industries have prompted a closer look at residue utilization.

Before marketing studies and economic analyses of the feasibility of residue utilization can be made, it is first necessary to learn something about the quantities, characteristics, and accessibility of the residue. Such information is now available for softwoods in the Pacific Coast states *(Dell and Ward 1971; Howard 1971, 1973)* and the Intermountain area *(Brown 1974)*; however, comparable data for other regions (particularly hardwood areas) is either lacking or limited in scope.

The West Coast estimates of logging residues were obtained by sampling cutover areas by the line intersect method. The use of this technique for sampling logging residues was pioneered in New Zealand *(Warren and Olsen 1964)* and refined and retested in the United States and Canada *(Bailey 1969, 1970a, 1970b; Howard and Ward 1972; Menard and Dionne 1972; Van Wagner 1968)*. The method was found to be quite accurate and efficient. All these tests, however, were in softwoods. Therefore, we felt that before surveying residue in Appalachia, we should verify the accuracy of line intersect sampling in hardwood timber.

The Line Intersect Method

Line intersect sampling uses a sample line, or a transect, that may be continuous or segmented, located systematically (with reference to a grid network) or randomly, and can be measured in any units.

When a continuous line is used, its direction is usually changed in either a fixed or a random manner after a predetermined distance has been measured. When the line is not continuous, the segments may be oriented unidirectionally, randomly, or in groups (for example, paired at a right angle to each other).

The method then requires that whenever a piece of residue crosses the line, its diameter be measured at the point of intersection. The volume of residue is then estimated by using the equation:

$$V = \frac{\pi \Sigma d^2}{8L} \cdot \frac{43{,}560}{144}$$

Where:

V = volume of residue per acre, in cubic feet.

d = diameter of residue at point of intersection, in inches.

L = length of sample line, in feet.

If the sample line is measured in chains, the equation becomes:

$$V = \frac{\Sigma(.005454d^2)}{N} \times 1037$$

Where:

N = the length of the sample line in chains.

When information on defect, length, and end diameters is desired, it is very easy to make a subsample of a portion of the sample line (for example, every fourth chain) and measure the desired characteristics of residue pieces in the subsample, and perhaps add a classification code, in addition to the diameter at point of intersection.

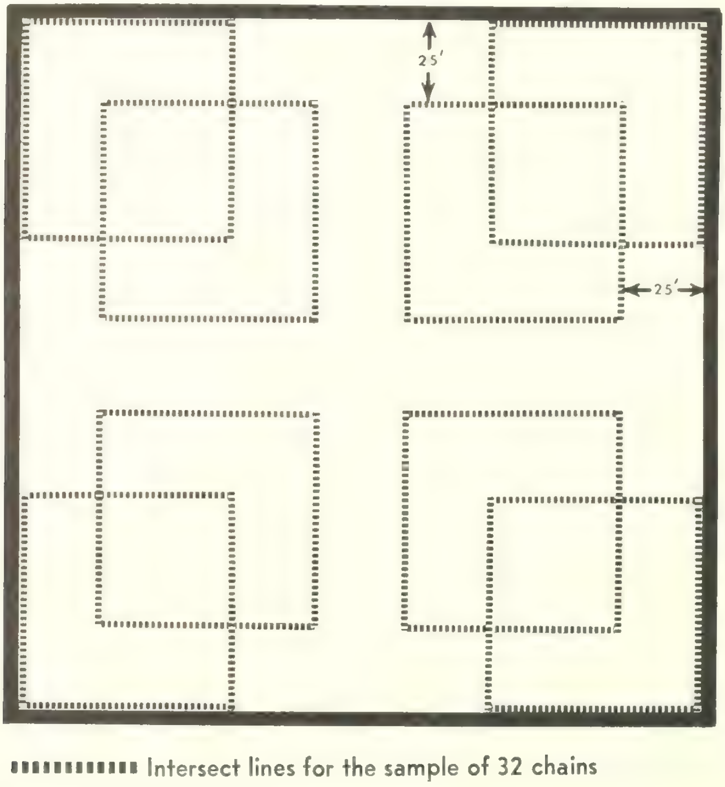
Study Methods

The objectives of this study were to see whether any characteristics of hardwood logging residues would cause bias in the line intersect method, and to determine what amount of sampling would be required to estimate residue volume to a given degree of precision.

To accomplish this required a means of ascertaining "actual" residue volumes for comparison with the estimates provided by the line intersect method.

In this study, actual volumes were obtained from a 100 percent tally of all residue pieces ($\geq$ 4.0 inches dob at the small end, and $\geq$ 4 feet in length) within a square 1-acre plot. Sixteen plots were established in different parts of West Virginia and measurements were taken between May of 1973 and May of 1974. Each plot was treated as a limited population of residue material. Hence, the tabulated volume for each plot will be referred to as the true or actual volume per acre. Volumes in gross cubic feet were calculated with Smalian's formula, using both end diameters and the length of each piece. Pieces that crossed one-

Figure 1.—A 1-acre plot (208.7 feet on each side) showing the arrangement of lines for the line intersect sample.



half of the plot's boundary were tallied; pieces crossing the remainder of the boundary were ignored.

Next the plots were sampled by the line intersect technique. Each plot was sampled along 32 intersect lines, each one chain in length. Figure 1 illustrates the arrangement of sample lines within one of the plots. As recommended by Bailey *(1969, 1970b)*, we subsampled 25 percent of the chains (8 chains per plot) to obtain measurements of end diameters and length.

Results

The volumes estimated by the line intersect sampling method are compared with the actual tallied volumes in table 1.

The mean percentage difference between the estimated and actual volumes was 8 percent. The 95 percent confidence interval about the mean percentage difference was 8 percent ± 11 percent. Therefore, we may be 95 percent confident that, if there is a consistent bias when the line intersect method is used with hardwood logging residues, it is between − 3 and + 19 percent. The fact that this interval includes zero means that we can't reject the hypothesis that there is no bias.

Table 1.—Actual gross volume of residue and that estimated from the sample (in $ft.^3$/acre) for the 16 plots

Plot no.	Volume of residue		Difference between estimated and actual volume
	Actual	Estimated	
	Cubic feet		*Percent*
1	290	231	−20
2	655	814	24
3	204	176	−14
4	805	831	3
5	672	868	29
6	761	808	6
7	264	360	36
8	169	134	−21
9	1,297	1,638	26
10	354	398	12
11	925	916	− 1
12	397	443	12
13	222	327	47
14	150	172	15
15	199	195	− 2
16	102	83	−19
Mean	467	525	8

BIAS IN DIFFERENT SITUATIONS

In general the line intersect method was reliable. But are there situations in which it is biased? To provide at least a partial answer to this question, we divided the 16 plots according to various characteristics.

- Oak plots versus nonoak plots (a plot with more than 50 percent of the pieces from oak species was considered an oak plot).
- Plots with roads versus plots without roads (a plot with one or more skid trails or haul roads intersecting its boundaries was considered to be a plot with roads).
- Plots in partially cut areas versus plots in clearcut areas.
- Flat plots versus steep plots (a flat plot was one with an average slope ≤ 20 percent ($\bar{x} = 9\%$); a steep plot, ≥ 30% ($\bar{x} = 38\%$)).
- Plots with short residue pieces versus plots with long pieces (a plot was in the "short" category if fewer than 50 percent of the pieces were over 12 feet long).

Table 2.—Comparison of estimated volume to actual volume for selected "treatment" categories

Category	Average volume per acre		Difference between estimated and actual volume
	Actual	Estimated	
	Cubic feet		*Percent*
Oak (n=10)	392	415	6
Nonoak (n=6)	592	707	19
Road influence (n=8)	430	514	20
No road influence (n=8)	504	535	6
Partial cuts (n=10)	605	694	15
Clearcut (n=6)	236	242	3
Flat (n=10)	328	362	10
Steep (n=6)	698	795	14
Short pieces (n=9)	276	311	13
Long pieces (n=7)	712	799	12

The results of these comparisons are shown in table 2. To evaluate them, a modified analysis of variance was performed. It showed that none of the interaction terms or main effects was significant. In other words, we could not reject the hypothesis that all differences were due to chance (random variation).

SAMPLE SIZE

The desired sample size can be computed from the mean variance within the plots for various levels of precision. Sample sizes were computed by the standard formula; the results are presented in table 3. When these recommendations are followed, we may be 95 percent confident that the final volume-per-acre estimate will have at least the specified degree of precision with the number of chains given.

Table 3.—Length of sample line needed for various degrees of precision (in chains)

Degree of precision	Length of sample line
Percent	*Chains*
±10	680
±15	302
±20	170
±25	109
±30	76
±35	55
±40	42
±45	34
±50	27

$$n = \frac{t^2CV^2}{DP^2}$$

Where: n = required number of sampling units (chains)
t = "student's" t-value at the 95 percent confidence level
CV = coefficient of variation in percent
DP = desired degree of precision in percent

Since these are guidelines based on average coefficient of variation found in this study (133 percent), they should be tempered by the characteristics of the residue to be sampled. For example, areas where the pieces vary greatly in size and the residue is noticeably clumped should be sampled more intensively than areas where the residue is uniform in size and distribution.

SAMPLING TIME

When field measurements were being collected, a record was kept of the time spent by a two-man crew. On the average, 3.7 hours were required to measure a 1-acre plot (this excluded lunch breaks but included any other rest periods). Sampling with the line intersect method (with a 25 percent subsample), required an average of 5 minutes per chain (excluding lunch breaks but including rest periods and walking between sampling units).

We also found that the time required was related to volume per acre and to the type of cut (clearcut areas required more time than partially cut areas). As can be seen in figure 2, the effect of volume per acre was more pronounced when an entire 1-acre plot was measured than when the line intersect method was used.

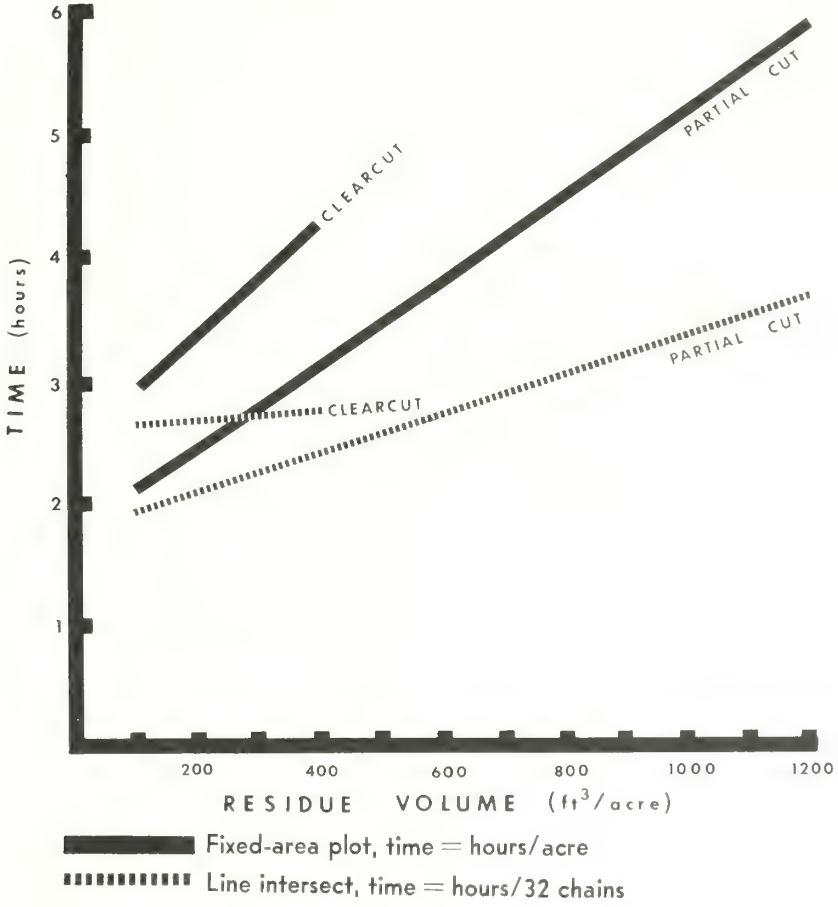
The effect of slope on sampling time was also examined, but very little relationship was found. Measurement time for the fixed 1-acre plots increased slightly as slope increased from 0 to 45 percent; however, there was no noticeable increase in the time required for line intersect sampling.

If we look at what could be accomplished in an 8-hour day (on partial cuts only, using "curved" values from figure 2) we find:

	Amount sampled in an 8-hour day	
Volume/acre (ft^3)	*Fixed plots (acres)*	*Line intersect (chains)*
200	3.3	122
400	2.6	107
600	2.1	95
800	1.8	85
1000	1.5	77
1200	1.4	70

Our study was not designed to compare sampling time for fixed-area plots against that with the line intersect method, but other studies *(Warren and Olsen 1964, Van Wagner 1968, Bailey 1969, Menard and Dionne 1972)* all report that the line intersect method requires only one-fifth to one-third the time normally spent with fixed-area plots.

Figure 2.—Residue sampling time plotted against volume per acre for clearcuts and partial cuts.



OTHER CONSIDERATIONS

There are considerations other than accuracy, time, and cost that affect the choice of a sampling method. For example, with fixed area plots, there must be some criteria for pieces that overlap the plot's boundary, and they must be easily interpreted by the field crew. With line intersect sampling, there is no boundary; therefore, no guidelines are needed.

Another factor of considerable importance to the field crew is the ease of determining what has been measured. With fixed plots, we found it necessary to mark each measured piece to avoid missing some and remeasuring others. When the line intersect method is used, there is no problem because measuring proceeds systematically along the sample line.

Thus, in general, line intersect sampling is a boon to the field worker because there is less ambiguity and decision-making is held to a minimum. There is also a psychological benefit in being able to see readily what has been accomplished and what lies ahead, and in having confidence that the completed work is up to standard.

Conclusions

- The line intersect method will provide a reliable and unbiased estimate of the volume of hardwood logging residues with a minimum expenditure of time and money.
- Reliability of the line intersect method is little affected by species, type of cut, slope, road influence, or length of residue pieces.
- Sampling time is directly related to volume per acre and type of cut, and the advantage of line intersect sampling over the fixed-plot design is greater at the higher volumes.

- The line intersect method is attractive to field personnel because it requires fewer decisions and gives them greater confidence than the fixed-plot method.

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6 p., illus. (USDA For. Serv. Res. Pap. NE-339)

The line intersect method for sampling logging residues was tested in Appalachian hardwoods and was found to provide unbiased estimates. The effects of species, cutting method, slope, road influence, and piece length were found to be nonsignificant. The length of sample line required for various levels of precision is given.

524.69 : 332.3

Keywords: Logging residue, line intersect, sampling

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Stand Structure and Stocking Control in Appalachian Mixed Hardwoods

by George R. Trimble, Jr. and H. Clay Smith

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by George R. Trimble, Jr. and H. Clay Smith

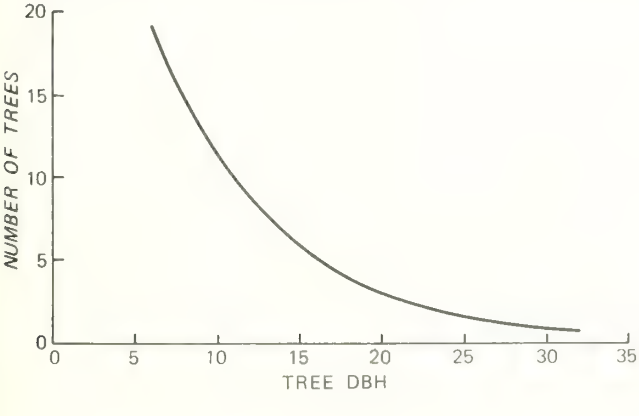
Abstract

Uneven-aged management using a "q" technique for structure control is discussed for Appalachian mixed hardwoods. The success in attaining stand structure goals with periodic selection cuts was evaluated. Where these goals had not been reached, the authors speculated, on the basis of current stand conditions, whether they would be reached, and if so, when. For successful control of stand structure, reasonable guidelines must be used for choosing maximum size trees, residual basal area, and a "q" that is applicable to the tree species and stand conditions. Under this system of management, the future stands will contain mainly tolerant species that produce lower volumes per acre than those presently composing the overstory.

IT IS GENERALLY RECOGNIZED that, to achieve sustained yield in stands regulated under uneven-aged management, the stands must be balanced; periodic removals must leave a stand whose structure and stocking are such that it can support equal periodic harvests indefinitely. The more important it is that periodic harvests be nearly equal in volume, the greater is the need to maintain a tailored stand structure so that yields by size classes will tend to stabilize. Where the strict interpretation of sustained yield is not adhered to (some variation is permitted either in the amount harvested at each periodic cut or in the length of time between cuts), such tight control of residual stand structure and stocking is not required. However, in this paper we will describe the feasibility of strict control of structure and stocking based on the application of a "q" guideline to two Appalachian mixed hardwood stands.

In 1898, a French forester, F. de Liocourt, showed that in uneven-aged stands the number of trees in successive diameter classes represents a geometric series, which means that the quotient between numbers in the classes is a constant. Meyer *(1952)* calls the quotient "q". This "q", represented graphically by a reverse J-shaped curve (fig. 1), has been found to be typical of uneven-aged stands in numerous locations *(Meyer 1952)*.

Figure 1.—Ideal stand structure for uneven-aged management is represented by a reverse J-shaped curve.



Study Methods

The woodlots where the study was made are located in the Fernow Experimental Forest near Parsons, West Virginia. Site quality is excellent, between 75 and 80 feet for oak. The forest type was Appalachian mixed hardwoods. The soil is a deep (more than 3½ feet) Belmont silt loam derived from limestone.

In 1948, when the study was begun, the stands were composed mainly of two age classes of trees: second-growth 40 to 45 years old, and older-growth trees left from the original cutting that took place between 1905 and 1910. In addition, a scattering of small poles occupied openings created by the death of the American chestnut around 1930.

Both research areas were designated for treatment by individual tree selection systems, but with the following difference. Area A was designated for sawlog management, in which we were concerned only with the trees over 11 inches dbh. Area B was designated for sawlog and small product management, in which we managed the stems down to 5 inches. Each research area covered 5 acres.

To define a stand structure goal based on a "q" guideline, three kinds of information are needed: the ratio of "q", the dbh of the maximum-size tree to be left after each cutting, and the basal area after cutting. After these three parameters have been chosen, the residual stand-structure goal can be determined mathematically (fig. 2).

Example

Given: Q = 1.3; Maximum dbh = 32; Basal area in trees over 5.0 inches dbh = 80

Method

Dbh	(1) No. trees (trial first step)	(2) Basal area (trial step)	(3) No. trees (final step)
6	30.29	5.95	19.37
8	23.30	8.13	14.90
10	17.92	9.77	11.46
12	13.79	10.83	8.82
14	10.60	11.33	6.78
16	8.16	11.39	5.22
18	6.27	11.08	4.01
20	4.83	10.54	3.09
22	3.71	9.79	2.37
24	2.86	8.98	1.83
26	2.20	8.11	1.41
28	1.69	7.23	1.08
30	1.30	6.38	.83
32	1.00	5.59	.64
Total	--	125.10	--

Steps

1. Number of trees in column 1 based on "q" of 1.3. Multiply column 1 by basal area for the dbh class = column 2
2. Total column 2
3. Divide 80 by total of column 2 = factor

$$\frac{80}{125.10} = .639$$

4. Multiply each number in column 1 by factor = column 3.
5. Check on basal area (accumulate multiply column 3 by basal area for dbh class) = total basal area = 80.02.

Figure 2.—Allocation of trees by diameter classes to set a given "q" when maximum diameter and basal area are given.

We chose a residual basal area (table 1) based on local experience *(Trimble 1968)*. A maximum-size tree (table 1) was designated, based on growth characteristics of the species present and the objective of growing a few really large trees per acre. Selecting a "q" was more difficult because we had no locally determined information except the various "q"s computed for existing managed stands. (The procedure for computing "q" from a stand table is shown in appendix I.) Because these were for second-growth stands with a relatively large number of small trees, the ratios were high, mostly in the range of 1.5 to 1.8.

We believed that under management a lower quotient would be feasible and would result in a greater proportion of the residual stand being occupied by larger trees. Therefore, a higher proportion of the stand growth would be put on these larger and more valuable stems. In other words, greater efficiency.

Keep in mind that the "q" ratio refers to the numbers of trees in successive diameter classes. The lower the "q", the less the difference in number of trees between diameter classes. A "q" of 1 would mean that all dbh classes had the same number of trees; and a "q" of 2 would mean that, if the 20-inch class had 1 tree, the 18-inch class would have 2 trees, the 16-inch class would have 4 trees, and so on.

We chose a "q" of 1.3 (table 1), which gives a much flatter J-shaped curve than is found in most natural second-growth stands. We hoped it would be steep enough to provide sufficient numbers of trees to feed into and maintain the progressively larger dbh classes.

We recognized that other goals could have been set for residual basal area, maximum-size tree, and "q". However, since we were not testing differences between levels of these parameters, we had to decide on specific goals, and our experience indicated that these were reasonable.

Our first cutting in both stands was a conditioning cut; we got rid of the poorer trees—and yet made profitable cuts—without paying much attention to balancing the stand structure as defined by our goals (table 1). After the first cut and up to the present, our main concern has been to increase the tree population where needed all along the J-shaped curve and to cut within the ranges of surplus trees. Our guiding policy has been to leave enough trees above the curve in the surplus classes to balance the basal-area deficiencies created by the minus diameter classes. (Table 2 shows the scheduling of

Table 1.—Actual stand conditions and goals of management

Area	"q"	Maximum size tree dbh	Basal area[a]		Cutting cycle	Volume[b]
			In trees 5 to 11 inches dbh	In trees over 11 inches dbh		
		Inches	*Sq. ft.*	*Sq. ft.*	*Years*	*M bd. ft.*
ORIGINAL STANDS						
A	1.5	36	17.2	85.8	—	14.2
B	1.5	32	22.2	83.6	—	13.4
STANDS 24 YEARS LATER (4 YEARS AFTER LAST CUT)						
A	1.5	30	28.9	69.8	—	11.9
B	1.4	32	18.3	76.4	—	13.6
STAND GOALS (AFTER-LOGGING CONDITIONS)						
A	1.3	32	(c)	65	10	11.9
B	1.3	32	15	65	10[d]	11.9

[a] Basal area includes living culls where found.

[b] Board-foot volume in International ¼-inch kerf rule to an 8-inch top inside bark in trees over 11 inches dbh includes living culls in original stand, no culls in later years.

[c] Uncontrolled.

[d] Two of the 4 times area B was cut, it was cut on a 5-year cycle.

Table 2.—Schedule of inventories, cuts, and "q" ratios

Stand operation	Volume removed/ acre	Residual volume/ acre	Residual[a] basal area/ acre	Residual[a] stand "q"
	M bd. ft.[b]	*M bd. ft.*[b]	*Sq. ft.*	
		AREA A		
1948—Inventory	—	14.2	85.8	1.5
1948—Cut	7.6	6.6	43.0	1.3
1953—Inventory	—	8.9	55.1	1.3
1958—Inventory	—	11.0	66.7	1.3
1958—Cut	2.0	9.0	54.1	1.7
1963—Inventory	—	10.9	64.5	1.6
1968—Inventory	—	12.4	73.1	1.5
1968—Cut	2.2	10.2	60.6	1.5
1972—Inventory	—	11.9	69.8	1.5
		AREA B		
1948—Inventory	—	13.4	105.8	1.5
1948—Cut	6.7	6.7	57.6	1.6
1953—Inventory	—	9.5	76.0	1.6
1958—Inventory	—	12.2	93.7	1.6
1958—Cut	2.1	10.1	76.5	1.5
1963—Inventory	—	12.0	88.4	1.5
1963—Cut	0.7	11.3	81.4	1.5
1968—Inventory	—	13.5	96.1	1.5
1968—Cut	1.7	11.8	84.1	1.4
1972—Inventory	—	13.6	94.7	1.4

[a] In trees over 11.0 inches for area A; in trees over 5.0 inches for area B.
[b] In trees over 11.0 inches for both areas.

inventories, and the cuts, board-foot volumes, and basal areas involved. Note that we varied the cutting cycle for area B, and only after the last cut (in 1968) did we decide definitely to use a 10-year cycle rather than a 5-year cycle.)

Results

We evaluated the degree of success that has been attained to date in reaching stand-structure goals. And where these goals have not yet been reached, we speculated—on the basis of current stand conditions—whether they would ever be reached, and if so, when. We also examined the various stand factors that seem to be associated with the changes that have taken place on these areas since the study was begun. We made all of these determinations separately by areas.

Area A

We looked first at the goal for *maximum-size trees* to be left. This calls for a maximum dbh tree of 32 inches, at a density of 0.64 of these trees per acre. In the original stand, the density of 32-inch trees, plus larger stems, was only 0.40 trees per acre. Because all trees in the stand larger than 30 inches were poor old-growth residuals, they were removed in the first cut. In the following two cuts, most of the slightly smaller old-growth stems were removed for the same reason. Thus at the time of the last recruise, in 1972, the largest size tree in the 5-acre area was 30 inches. There is no doubt, however, that we can attain the maximum-size tree goal. The species involved can grow to much larger diameters; it is only a question of time until some of the larger second-growth stems are 32 inches dbh. In 1988, it should be possible to retain in the residual stand the goal of 0.64 of a 32-inch tree per acre. This would be 40 years after the stand was first cut and after a total of 5 cuts.

We then examined the *basal-area* goals. We are shooting for residual basal area of 65 square feet in the sawtimber portion of the stand; basal area in poles is uncontrolled (table 1). The original stand had 85 square feet, but the first cut reduced it to 43 square feet (table 2); the stand was overcut in the first harvest because in the unmanaged condition it had so many poor-risk and undesirable trees. From then on, we gradually increased the residual stocking; but after the last cut, in 1968, we were still 4.4 square feet below the goal of 65 square feet. Four years later, in the 1972 recruise, the stand had 69.8 square feet (table 2). At the present rate of increase of 2.3 square feet annually, when the next cut is made (in 1978) the stand will have a basal area of 83.2 square feet. This will provide for a profitable cut of between 2 and 3 thousand board feet (current growth is about 425 board feet per year) and still leave a stand of 65 square feet.

A "q" was computed for the stand whenever an inventory was taken and after every cut (table 2). The resultant *array of "q"s* starts at 1.5 for the original stand, drops to 1.3 after the first cut, rises to 1.7 after the 1958 cut, and holds at 1.5 for the last three computation periods (table 2). The fact that we computed a "q" of 1.3 for three periods — 1948, 1953, and 1958 — demonstrates that the average slope of the line (which the "q" is) resulting from plotting numbers of trees over dbh classes can coincide with the "q" goal even though the following stand structure goals are not met: (1) the curve is not smooth and does not coincide with the tree distribution goal, (2) the actual basal area does not equal the basal area goal, and (3) the maximum-size tree goal is not met. (Figure 3 — the plotted curve for the 1948 after-cutting stand — illustrates this situation.) The plotted data from the 1972 cruise (fig. 4) indicate that when the basal-area goal is met for the larger dbh classes (projected for 1988) it will be possible to cut to the theoretical J-shaped curve goal; that is, the stand will contain enough trees above the line to make a profit-

Figure 3.—J-shaped curve for the area A stand structure after the 1948 cut, contrasted to the ideal curve based on the stand structure and stocking goals.

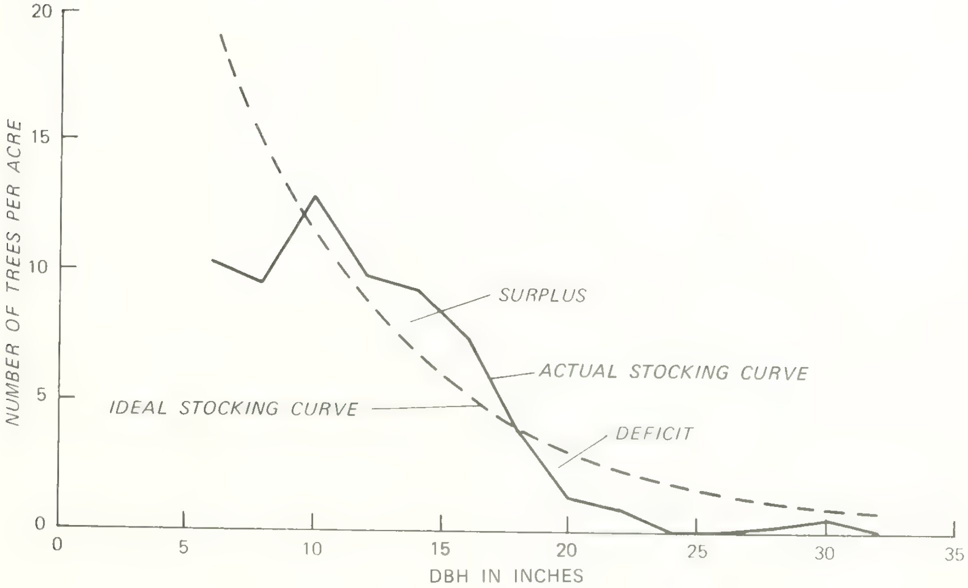
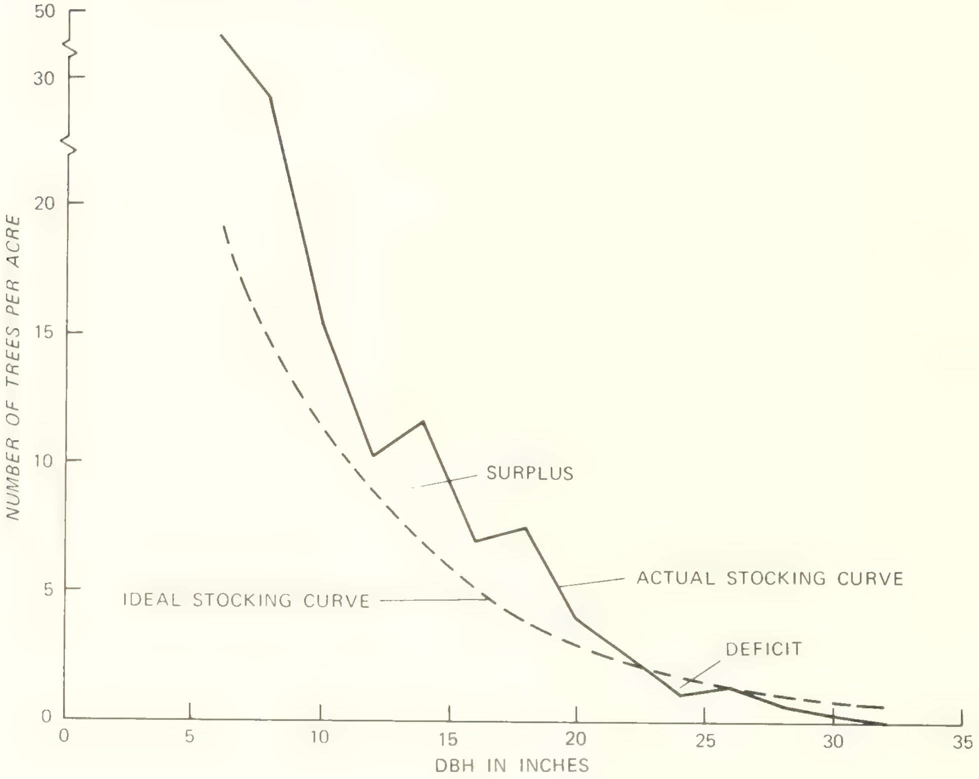


Figure 4.—J-shaped curve of area A stand structure for the 1972 inventory and the ideal curve based on stand structure and stocking goals.



able cut and leave a stand that meets the structure and stocking goals.

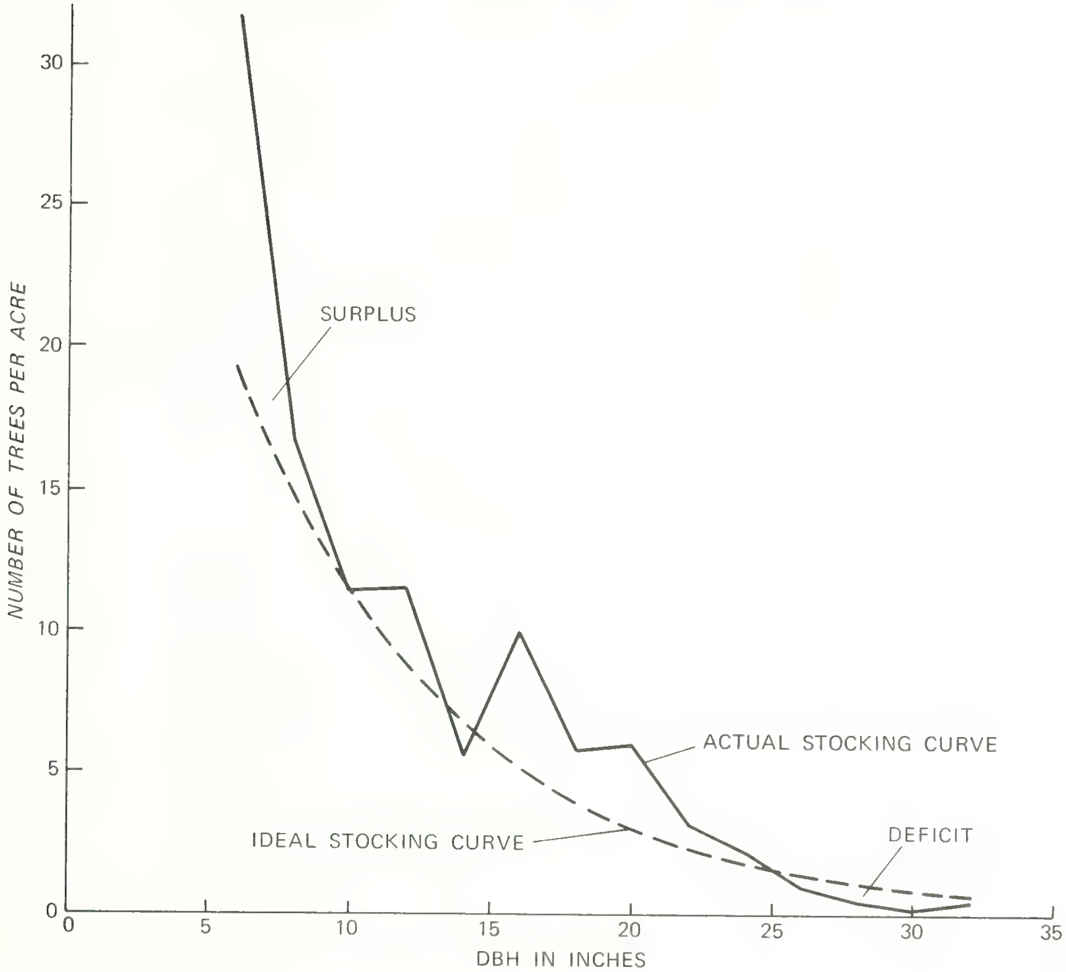
Area B

The *maximum-size tree* situation in area B was almost identical to that in area A: the original second-growth stand contained a scattering of large old-growth residuals, most of which were removed in the four cuts made since the study was started. At the 1972 cruise, density of the 32-inch trees was 0.4 of a stem per acre. As with area A, we anticipate that after the 1988 cut we will achieve our goal of 0.64 of a 32-inch tree per acre in the residual stand. This would be 40 years after the stand was first cut and after a total of 6 cuts.

The *basal-area* goal for area B is 80 square feet in the after-cutting stand, 65 square feet in sawtimber trees and 15 feet in poles (table 1). After the first cut, which was deliberately very heavy to remove many poor trees, we retained only 57.6 square feet per acre (table 2). During the past 24 years of management we have gradually built this up until, after the 1968 cut, we reached a residual basal area of 84.1 square feet—4.1 feet more than our goal of 80 square feet. Four years later, at the time of the 1972 cruise, the stand had 18.3 and 76.4 square feet in poles and sawtimber trees respectively (table 2). From now on, we should have no difficulty cutting to our basal-area goal and, at the same time, should make profitable cuts.

The *array of "q"s* computed for area B starts at 1.5 for the original stand, rises to 1.6, and then drops to 1.4 for the 1968 after-logging stand and the stand at the time of the 1972 cruise (table 2). Plotting number of trees per acre over dbh from the 1972 cruise data shows that the only obstacle to cutting to the stand structure and stocking

Figure 5.—J-shaped curve of area B stand structure for the 1972 inventory and ideal curve based on stand structure and stocking goals.



levels as defined is the lack of sufficient trees in the larger dbh classes (fig. 5). This deficiency should be satisfied by the time of the 1988 cut; and from then on we should be managing the stand in conformity with the established guidelines.

Discussion

This experiment is, as far as we know, the most intensive and the longest extended test of this type of selection silviculture in hardwoods in the United States. We believe that enough time has elapsed and a close enough look been taken at the results to state with confidence that this is a feasible system if reasonable guidelines are followed. By reasonable guidelines we mean choosing maximum-size trees, residual basal area, and "q"s that are applicable to the species of trees and the conditions of the stands that are under consideration.

We feel that a fair amount of leeway exists to successfully vary the guidelines used in this particular study. For example, a "q" of 1.5, 1.6, or even higher would most certainly work out; but it seems unlikely that a "q" much lower than 1.3 would provide enough growing space for small stems.

The dbh of the maximum-size leave tree could certainly be lowered several inches, even for sawlog management; or it could be raised. It is likely that because of change in species composition on these areas — from predominately intolerant to mainly tolerant trees — a reduction in dbh goals for maximum-size tree would be in order after 40 to 60 years.

From stocking studies made in a similar stand, we feel that the residual basal area is within a few square feet of the minimum necessary for maximum growth, but this figure could probably be raised some without making any difference in growth — though carrying charges on the residual stand would be higher and net profits therefore lower.

Many foresters have questioned whether ingrowth from the smaller diameter classes would be sufficient to fulfill the needs of the larger classes. Originally, there were few stems in the 1- to 5-inch class, but with cutting in the overstory these became abundant. In 1948, area A had 50 stems per acre and area B had 22; in 1963 (when the last small-stem count was made), area A had 412 stems per acre and area B had 300. Most of the small-stem population is composed of the very tolerant sugar maple; without a good-growing tolerant species available, it is doubtful if this type of cutting practice could be made to work.

Throughout the period of this study, the stand has contained enough 6- through 10-inch pole-size stems to supply trees to the sawtimber-size stand. Originally, area A contained 50 poles per acre and area B had 63; in 1972 area A had 91 poles per acre and area B had 60. The big increase in number in area A is because no cutting was done among these size classes. During the study period, the increase in proportion of sugar maple has been remarkable: for area A, from 18 percent of the pole stand in 1948 to 54 percent in 1972 and for area B, from 17 to 68 percent. The proportion of small sawtimber sugar maple (stems from 11 to 19 inches dbh) has increased also — for area A from 5 to 19 percent, and for area B from 11 to 21 percent.

The original pole and sawtimber canopy, most of which came in after a very heavy cut, was composed of a mixture of tolerant and intolerant species (table 3). The new stand, as indicated by the increase in sugar maple among the smaller stem components, will be composed mostly of tolerants. (See appendix II for scientific names of species.)

The per-acre board-foot volumes (tables 1 and 2) are based on local volume tables derived for individual species by site classes. In the computations, the future stand volumes as well as the past and present stand volumes were determined for the sawtimber-size trees present on the area. Because the past and present sawtimber stand contains many intolerant trees such as yellow-poplar that produce higher board-foot volumes than does sugar maple for trees of the same dbh, the volume of the future stands that will be comprised largely of sugar maple are overestimated. Thus, instead of a future residual per acre volume of 11.9 thousand board feet, we will carry a somewhat lower volume even with the same diameter and basal-area distributions.

Judging the merits of this silvicultural system by the results of tests on small 5-acre units could be misleading. However, we have tried the same system on several areas ranging in size up to 90 acres. Though these trials on larger areas have been under way a shorter time, and fewer cuts have been made, the same kinds of results are indicated. Some of these larger areas are of comparable site quality; others have site indexes 10 feet or so lower. On the areas of lower site quality, beech and red maple largely replace sugar maple as the species of the future.

In applying this system to larger areas, we group the trees into broader diameter classes than the 2-inch classes we used on the 5-acre study areas. We have been using 4 dbh groups: pole timber 5 to 11 inches, small sawtimber 11 to 17 inches, medium sawtimber 17 to 23 inches, and large sawtimber over 23 inches. This classification seems to give good results. If we group the future residual trees in area B by this method, we get the following numbers of stems per acre: poletimber 45.7, small sawtimber 20.8, medium sawtimber 9.5, and large sawtimber 5.8.

Table 3.—Species composition—number of merchantable stems in 5-acre plots

Species	Area A			Area B		
	1948: original stand	1958: after cutting	1972	1948: original stand	1958: after cutting	1972
6- TO 10-INCH DBH						
Yellow-poplar	40	32	24	63	17	12
Black cherry	17	11	7	33	18	3
White ash	19	17	14	29	26	9
Red oak	12	23	27	17	14	6
Hickory	59	36	21	44	16	11
Sugar maple	44	127	247	54	123	205
Beech	13	12	15	23	4	10
Sweet birch	8	14	18	24	25	25
Other	38	47	83	26	19	19
Total	250	319	456	313	262	300
12- TO 18-INCH DBH						
Yellow-poplar	27	28	35	52	64	43
Black cherry	8	12	11	22	24	23
White ash	8	8	9	8	12	21
Red oak	2	2	3	2	4	5
Hickory	126	83	74	73	36	22
Sugar maple	11	20	34	25	22	34
Beech	16	3	4	24	3	1
Sweet birch	7	—	1	7	2	7
Other	9	3	10	23	6	9
Total	214	159	181	236	173	165
20-INCH-PLUS DBH						
Yellow-poplar	2	7	17	2	11	31
Black cherry	—	—	2	—	—	2
White ash	1	3	1	—	1	4
Red oak	8	3	3	2	1	3
Hickory	10	12	16	12	11	12
Sugar maple	16	5	7	10	11	11
Beech	4	—	—	5	1	1
Sweet birch	—	—	—	1	—	—
Other	4	1	1	4	1	3
Total	45	31	47	36	37	67

The forester who is considering using this silvicultural system should be aware of its disadvantages, among which are:

- Like any single tree selection system, it produces a stand composed almost wholly of the tolerant species that grow in the area; there is little opportunity to mold the stand composition.
- Frequent, highly accurate inventories are needed to determine what size classes of trees to cut and to leave.
- A high level of silvicultural expertise is required to handle the marking job.
- As in any individual tree selection system, the cost of logging is high, and the residual stand is subject to high risk from logging damage.

However, if a selection system is desired, and if strict control of sustained yield has high priority, then this kind of selection system may be the best. It should be stressed, however, that the specific guidelines used in this study can be applied with expectation of similar results only on comparable sites and in similar stands.

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1968. GROWTH OF APPALACHIAN HARDWOODS AS AFFECTED BY SITE AND RESIDUAL STAND DENSITY. USDA For. Serv. Res. Pap. NE-98. 13 p., illus.

Appendix

I

Computation of "q" from a stand inventory

The ratio "q" is computed through the use of the unweighted linear regression for: $Y = a + bx$

in which $Y = \log$ (No. of trees per acre)

$X =$ dbh class

For 1-inch classes, take the antilog of the "b" obtained in the above regression. This gives the "q". For 2-inch classes, multiply "b" by —2; then take the antilog; this gives the "q".

II

Common and scientific names of species referred to in this study

Ash,white	*Fraxinus americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, sweet	*Betula lenta* L.
Cherry, black	*Prunus serotina* Ehrh.
Chestnut, American	*Castanea dentata* (Marsh.) Borkh.
Hickory	*Carya* spp.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, northern red	*Quercus* rubra L.
Yellow-poplar	*Liriodendron tulipifera* L.

Trimble, George R., Jr., and H. Clay Smith.
1976. **Stand structure and stocking control in Appalachian mixed hardwoods.** Northeast. For. Exp. Stn., Upper Darby, Pa.
10 p., illus. (USDA For. Serv. Res. Pap. NE-340)

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228 : 221.4 : 535 : 176.1 -- (74)/(76)

Keywords—Uneven-age management (selection), structure control, "q", Appalachian hardwoods.

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